

Session 11

Closure

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SELECTED REFERENCES



FREDERICTON - MONCTON HIGHWAY
SAFETY REVIEW FOR THE
FUNCTIONAL DESIGN STAGE

DRAFT

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EXECUTIVE SUMMARY

The New Brunswick Department of Transportation (NB-DOT) has requested proposals from consortia to design, build, operate and transfer a new four-lane controlled access toll highway between Fredericton and Moncton. The functional design of the highway will be a major component of the proposal submission. To ensure that safety issues are explicitly considered as part of the functional design, Maritime Highway Corporation, one of the consortia invited to prepare a proposal submission, commissioned Hamilton Associates to independently review and comment on the safety features of the design. This report is the product of the independent safety review.

The objective of this review is to identify opportunities to make the design of the new Fredericton - Moncton Highway safer. It is acknowledged that safety is one of many considerations that the highways designers need to balance in the design process. Many of the recommendations of this report are therefore intended to prompt NB-DOT and MHC to consider the "safety value added" by enhancing specific highway design elements. At the same time, some of the issues identified in this safety review may be incorporated into the revised functional design drawings which will be submitted as part of the MHC proposal.

This safety review was based upon the functional design drawings prepared by MHC, the project Request for Proposal (RFP) including the design criteria, and supporting background documents.

The safety review was undertaken in a relatively short time frame, and therefore only encompasses the general design features and geometric elements. Not all items were reviewed in detail, and some recommendations in this report are simply intended to highlight features which should be checked at the functional or detailed design stages.

The results of the safety review are presented under the following headings:

- Vertical Alignment
- Horizontal Alignment
- Cross Section Elements
- Interchanges
- Traffic Operations and Control
- The Toll Plazas
- Other Issues

The findings and recommendations of the safety review addressing individual design elements are presented individually under each sub-section. Some recommendations are for MHC to review location-specific design elements to justify standards used (for example for some interchange elements), or to address safety concerns (for example to avoid ponding). Other recommendations are for the joint consideration of MHC and NB-DOT to enhance safety on the highway (for example by reviewing shoulder width design requirements). Finally, the section on the Toll Plazas addresses the safety features of the design concept proposed by MHC, and recommends alternatives for further consideration.

It is recommended that continued safety input be obtained during the detailed design stage to ensure that safety issues continue to be explicitly addressed. By continuing to place an appropriately high emphasis on road safety at all the stages of this project, MHC and NB-DOT will ensure delivery of a high quality modern highway.

1.0 INTRODUCTION

1.1 Background

The New Brunswick Department of Transportation has requested proposals from consortia to design, build, operate and transfer a new four-lane controlled access toll highway between Fredericton and Moncton. Maritime Highway Corporation (MHC) is submitting a proposal in response to this request.

The functional design of the highway will be a major component of the proposal submission. To ensure that safety issues are explicitly considered as part of the functional design, MHC commissioned Hamilton Associates to independently review and comment on the safety features of the design. This report is the product of the independent safety review.

1.2 Context

The objective of this review is to identify opportunities to make the design of the new Fredericton - Moncton Highway safer. In doing so, it is acknowledged that safety is one of many considerations that the highways designers need to balance in the design process, including cost, the environment, geotechnical conditions and right-of-way availability. This review is therefore focused on safety, with the anticipation that in general, the findings will be used as input to the design, rather than as a design requirement. Many of the recommendations of this report are intended to prompt the New Brunswick Department of Transportation and MHC to consider the "safety value added" by enhancing specific highway design elements.

It is also important to note that from an overall transportation network perspective, it is expected that building the Fredericton - Moncton Highway will in itself improve the safety of vehicle travel in New Brunswick. The October 1995 Transportation Issues and Assessment of Alternatives report by Washburn & Gillis Associates estimated that the new highway will save more than 3,600 vehicle crashes over a 20 year period compared to the existing highway connections.

Finally, it is stressed that as long as there are vehicles on the road, there is no "absolutely safe" highway. There are simply varying degrees of safety, and the goal of the design should be to provide a highway which is as safe as possible within the project constraints.

Within this context, this safety review aims to provide advice to the design team in order to deliver a safer highway

1.3 Basis

This safety review was based upon the functional design drawings prepared by Maritime Highway Corporation (MHC). The safety review was undertaken as part of the internal peer review initiated by MHC in May and June, 1997. In addition to reviewing the drawings, the safety review consisted of reviewing the project Request for Proposal (including the design criteria) and supporting background documents, as well as discussions with MHC engineers to gain insight into the design issues.

It is expected that many of the issues identified in this safety review will be incorporated into the revised functional design drawings which will be submitted as part of the MHC proposal.

The safety review was undertaken in a relatively short time frame, and therefore only encompasses the general design features and geometric elements. Not all items were reviewed in detail, and some recommendations in this report are simply intended to highlight features which should be checked at the functional or detailed design stages. It is recommended that continued safety input be obtained during the detailed design stage to ensure that safety issues continue to be explicitly addressed.

2.0 VERTICAL ALIGNMENT

2.1 Maximum Vertical Grade

A. Comments on Design Criterion

A maximum vertical grade of 5.0 percent was specified by the design criteria for the Fredericton-Moncton Highway. A review of Canadian and international design standards indicated that for high-speed controlled-access facilities, the maximum grade is typically 3.0 percent for "level" terrain or 4.0 percent for "rolling" terrain. A maximum grade of 5.0 percent is usually only specified for "mountainous" terrain. According to discussions with MHC engineers, the terrain along the Fredericton-Moncton Highway alignment is undulating, and perhaps best classified between "rolling" and "mountainous".

In the future, it may be desirable for the New Brunswick Department of Transportation to review the required maximum vertical grade design standards for different terrain types. A clarification of the classification of the terrain for the Fredericton - Moncton Highway alignment would also be desirable.

From a safety perspective, mild vertical grades are preferred to steep grades. Steep grades provide more stress on the driver and the vehicle, increase the speed differential between vehicles, and encourage more passing and lane changing manoeuvres. This results in the potential for more driver errors and vehicle breakdowns.

B Functional Design Review

The review of the functional design drawings indicated that the maximum vertical grade of 5.0 percent had generally been adhered to. One section which marginally exceeded 5.0 percent is presented in APPENDIX A. The majority of the vertical alignment did not exceed a maximum grade of 4 percent. There are therefore no safety concerns with this aspect of the design.

2.2 Minimum Grade

The typical minimum design grade of 0.5 percent was specified in the design criteria. The criteria also indicated that a flat grade may be needed through the Grand Lakes Meadows area (east of the Saint John River crossing area) for environmental reasons. The review of the functional design drawings indicated that a minimum design grade of less than 0.5 percent was used along some sections, as presented in APPENDIX A. A few of these locations coincided with horizontal curves, as indicated in APPENDIX A, raising the possibility of a flat cross fall (due to super-elevation) coinciding with a flat vertical profile. The design of these sections should therefore be reviewed in detail to minimize any potential for ponding.

2.3 Other Vertical Alignment Elements

The design criteria specify a minimum K value of 105, and a minimum vertical curve of 120 metres. These criteria are desirable from a safety perspective to reduce the risk of fixed-object and loss-of-control crashes. The functional design drawings should be reviewed to ensure that these criteria were adhered to.

3.0 HORIZONTAL ALIGNMENT

3.1 Minimum Radius

A minimum horizontal turning radius of 750 metres was specified in the design criteria. However, the criteria requested that radii of less than 1,500 metres be justified. The review of the functional design drawings indicated that all of the horizontal turning radii were larger than 750 metres. However, radii of less than 1,500 metres were identified at several locations, as identified in APPENDIX B.

According to the design criteria, the functional design needs to provide justification for each instance when a radius of less than 1,500 metres is used. Once these justifications are available, they can be reviewed from a safety perspective.

In general, for a maximum mainline super-elevation of 6.0 percent (as required by the design criteria for this project), radii of more than 750 metres are considered adequate from a safety perspective for the highway design speed of 120 kilometres per hour, and this issue does not raise any safety concerns.

3.2 Adjacent Horizontal Curves

The design criteria require that a minimum tangent section of 500 metres be provided between two horizontal curves. This is desirable from a safety perspective to reduce the potential for off-road crashes. The functional design drawings should be reviewed to ensure that this criterion was adhered to.

3.3 Stopping Sight Distance

The effect of the horizontal and vertical geometry on stopping sight distance is generally closely examined during the design. However, sight distance can also be affected by barriers, guard-rails and trees along horizontal curves, and these features are sometimes overlooked.

Guard-rails placed adjacent to curve sections could impede sight distance and reduce it to less than the minimum 240 metres specified in the design criteria. This is particularly true on curves with radii less than 1,005 metres. The functional design should therefore be reviewed to identify any such areas of concern both along the mainline and on the interchange ramps and loops. One such example was found at Station 134 + 400 along the eastbound lanes.

4.0 CROSS SECTION ELEMENTS

4.1 Median Width

From a safety perspective, providing a wide median is desirable to reduce the potential for cross-over and fixed object type collisions. The design criteria allow for three median types.

- Type I, providing a median width of 72.6 metres
- Type II, providing a median width of 22.6 metres
- Type III, providing a median width of 6.6 metres with a median barrier.

Therefore, from a safety perspective, the use of the Type I median should be used whenever possible, while the use of the Type III median should be minimized.

The median width is measured between the edges of the travel lanes, and therefore includes the inside shoulder widths. The design criteria specify the locations along the alignment where each median type should be used. The Type III median was specified for only one location, near the Route 695 Interchange. This area is near the interface of design Sections 7 and 8, and a narrow median is needed due to environmental constraints.

A review of the functional design indicated that the Type III median was also used for a length of approximately 1,800 metres, near the interface of design Sections 4 and 5. The results of the median width review are shown in APPENDIX C. The need for a Type III median at this section should be reviewed in detail and justified.

Due to the reduced clear zone, barriers need to be provided in the transition sections between Types II and III.

4.2 Shoulder Widths

The design criteria require a 3.0 metre outside shoulder width, and a 1.5 metre inside shoulder width along the mainline of the highway. However, only 0.8 metres of the shoulder widths are required to be full strength pavement. The rest of the shoulder width may remain unpaved. This is similar to the typical Ontario shoulder design standards.

There is a consistent documented relationship between increasing the paved shoulder width and reducing collisions. Other provinces, such as British Columbia, require the full shoulder width to be paved on all highways. It is therefore recommended that the New Brunswick Department of Transportation and MHC examine the added value (including safety and maintenance benefits) of paving the entire width of both the inside and outside shoulders. As a start, consideration can be given to providing a full paved shoulder along horizontal curves, where the likelihood of off-road and loss-of-control collisions increases.

4.3 Bridge Shoulder Widths

The design criteria specify the following bridge shoulder width requirements:

- 3.0 metre outside shoulders and 2.5 metre inside shoulders for bridges shorter than 100 metres.
- 2.0 metre outside shoulders and 1.5 metre inside shoulders for bridges longer than 100 metres.

Reducing the shoulder width requirements on structures is primarily a cost saving measure. From a safety perspective, maintaining (as a minimum) the same shoulder width on the bridges as on the rest of the road is preferred, especially on longer structures where the likelihood of a vehicle breakdown or collision increases. The trend in the United States is to maintain full pavement width across bridges.

It is recommended that the New Brunswick Department of Transportation consider the value of revising the bridge cross-section standards to provide for the continuation of full-width shoulders on long structures. The benefit/cost trade-offs of maintaining a 1.5 metre inside shoulder on shorter structures (instead of widening to 2.5 metres) and maintaining a 3.0 metre outside shoulder on longer structures (instead of narrowing to 2.0 metres) may be worth evaluating.

4.4 Clear Zones

A Comments on Design Criterion

For the placement of longitudinal barriers to protect vehicles from road-side hazards, the design criteria reference the New Brunswick Highway Design Guide (Section 11 of the Highway Design Criteria and Standards section of the RFP). The Design Guide in turn refers to the TAC Manual on Highway Design for the definition of clear zones. According to the TAC Manual, a highway design speed of 120 kilometres per hour with a side-slope of 6:1 requires a clear zone of about 12 metres.

The TAC manual also requires that the clear zone be a function of the side slope and the horizontal curvature of the highway. The clear zone needs to be widened with steeper side-slopes, and also with increasing horizontal curvature.

However, in another section of the Request for Proposal (RFP), the clear zone appears to be defined and fixed at 10 metres. Specifically, Drawing 2.1B of the RFP (Typical Bridge Sections) defines the clear zone to be 10 metres for bridge piers.

It is recommended that the New Brunswick Department of Transportation clarify this issue. From a safety perspective, a wider clear zone is preferred.

B. Functional Design Review

During the detailed design stage, a detailed review is required to ensure that adequate barrier protection is provided for all bridge piers and other hazards which are within the clear zone (at least 10.0 metres, until the above issue is clarified).

Also at the detailed design stage, the added value of providing barrier protection for major hazards which are marginally outside the clear zone can also be considered.

4.5 Side-Slopes

The design criteria generally require a side-slope of 6:1 for vertical drops of 2.0 metres or less, 4:1 for vertical drops of between 2.0 and 5.0 metres; and 2:1 with guide rail for steeper drops. From a safety perspective, shallower side-slopes are preferred, and side-slopes which are steeper than 4:1 are considered unrecoverable.

The functional design drawings should be reviewed to ensure that the side-slopes are provided at least in accordance with the above criteria.

Longitudinal barriers for side-slopes between 2:1 and 4:1 need to be provided in accordance with the TAC Manual procedures. From a safety perspective, the TAC procedures are assumed to balance the hazard created by the guide rail with the side-slope hazard. At the detailed design stage, a drawing review should be conducted to ensure that barrier protection has been provided according to TAC procedures.

4.6 Guide Rail Characteristics

A Length

During the detailed design stage, it is recommended that the length of the required guard rails along the mainline and the interchange loops and ramps be checked to ensure compliance with New Brunswick and TAC design requirements

B End-Treatment

The design criteria do not specify the required end-treatment for guard rails. Similarly, the New Brunswick Highway Design Guide does not address this issue. The TAC Manual on Highway Design suggests several end-treatments, including buried/flared ends. However, recent practice avoids the use of buried/flared guard rails for safety reasons, especially the potential for "launching" vehicles.

In the United States, Ontario, and British Columbia, energy absorbing flared or tangent end-treatments have been adopted instead of buried/flared treatments. The 1993 NCHRP 350 report is typically being used as a guideline for new barrier designs.

It is therefore recommended that the end-treatment of guard rails along the Fredericton-Moncton Highway be in accordance with the latest practice elsewhere in Canada and the United States, and the use of buried/flared end-treatments be avoided.

5.0 INTERCHANGES

5.1 Overview

The design criteria outline specific requirements for four "major" interchanges, and separate requirements for the other "regular" interchanges. The major interchanges are expected to serve higher traffic volumes and connect to higher class roadways.

The functional design of the interchanges was reviewed at a preliminary level and compared to the design criteria. The results are summarized in APPENDIX D

5.2 Major Interchanges

A left-side merge was identified at Interchange B (East Fredericton High Speed Connector). The need for a left-side merge should be justified and alternatives explored.

Several apparent deficiencies were identified at Interchange D (Route 2 High Speed Connector). One horizontal radius was found to be below the minimum (340 metres compared to 440 metres); two vertical curve (one crest and one sag) appeared to have sub-standard K values, a vertical grade which is steeper than maximum was identified; and back to back vertical curves were identified. The design of this interchange should therefore be reviewed in detail to confirm that appropriate standards were applied.

5.3 Regular Interchanges

Several horizontal curves with less than the minimum required radius were identified, and the locations of these curves are summarized in APPENDIX D. The design of these curves should be reviewed to identify opportunities to for improving the turn radius.

6.0 TRAFFIC OPERATIONS & CONTROL

6.1 Traffic Operations

The predicted traffic volumes along the highway are relatively low. The AADT is expected to be around 7,000 vehicles per day near Fredericton, around 5,000 approximately mid-way between Fredericton and Moncton, and approximately 9,000 near Moncton. The two-way peak hourly volumes are expected to be between 400 and 750 vehicles per hour. In general, a four-lane freeway will provide excellent capacity and levels of service for this volume demand.

A preliminary review indicated that the spacing between the following interchanges was relatively close (less than about 4.0 kilometres).

- Longs Creek Interchange and Route 3 (St. Stephen) Interchange (2.3 kilometres)
- Route 7 Split (Fredericton East) and Nevers Road Interchange (less than 2 kilometres)
- Three interchanges in sequence: Waasis Road / Route 102 Interchange; Oromocto East Connector Interchange, and Route 7 / Route 660 Saint John Interchange
- Route 102 (Coy Town) Interchange and Old Route 2 (Jemseg) Interchange (about 4 kilometres)
- Route 2 (Trans Canada Highway) High Speed Connector to the River Glade High Speed Interchange

A further review of the separation between the on-ramps and off-ramps at these interchanges indicated that in general, sufficient separation (more than 900 metres) is provided to ensure efficient weaving operations. As well, the ramp volumes are anticipated to be relatively low, further reducing the potential for inefficient weaving operations.

However, as a value-added consideration, the potential for providing auxiliary lanes between two closely-spaced interchanges can be investigated. Alternatively, a Value Engineering analysis could examine the implications of postponing or canceling an interchange if it is close to another interchange. The safety implications of Value Engineering are discussed in Section 8 of this report.

6.2 Signing and Pavement Marking

Traffic control signs will be finalized at the detailed design stage. For the functional design plans, signing information is generally restricted to location and quantity. In finalizing the signing requirements, it is recommended that the following areas receive particular attention:

- *The approaches to the toll plazas on the mainline.* Due to the unusual mixture of high speed flow-through traffic with stopping traffic at the plazas, careful signing will be needed to guide drivers through these sections. As a minimum, this will require clear and early warning signs to:
 - ⇒ warn all drivers that a toll plaza is approaching;
 - ⇒ assign vehicles to the appropriate lanes (with/without transponders);
 - ⇒ warn vehicles without transponders of the need to stop, and
 - ⇒ assign vehicles without transponders to the appropriate lane (machine / booth payment).
- *The approaches to the ramp and loop toll stations.* These areas will require extremely careful, deliberate and repetitive signing and road cues because drivers do not typically expect any interference along freeway loops and ramps. Signing will be needed on the intersecting highways and arterials, with appropriate and carefully selected wording to prepare drivers for the toll stations.

Signing is especially critical since tourists and visitors (infrequent users) are expected to account for a significant portion of traffic on the highway

Due to the unusual nature of the above described signing conditions, the added requirement for bilingual signs, and the expected significant proportion of tourist traffic, it is recommended that a Canadian human factors expert be consulted in the development of the sign contents and the road features along these sections of the highway.

Along all roads connecting to the Fredericton-Moncton Highway, early warning signs will be needed advising drivers that this is a toll road.

Pavement marking will need to be reviewed in conjunction with the signing at the detailed design stage.

7.0 THE TOLL PLAZAS

7.1 Concept

The design criteria require that the highway provide an optional flow-through toll system. The highway will therefore need to provide a dual toll service:

- Flow-through uninterrupted service for vehicles equipped with Automatic Vehicle Identification (AVI) or Electronic Toll Collection (ETC) transponder technology; and
- Toll plaza service for vehicles not equipped with AVI and ETC technology

This dual toll service requirement stems from the need to equitably serve the significant tourist and recreational traffic which will use the highway infrequently, as well as the commuters and commercial vehicles who will use the highway on a more regular basis.

The proposed MHC solution to this design requirement provides a three lane cross-section (per direction) as a single flow through lane is developed to the outside of the two-lane mainline and proceeds uninterrupted through the toll area. The two mainline lanes then proceed to the toll plaza area, with one lane providing automatic coin machine (ACM) service, and the other lane providing full toll booth attendant service. The toll booth is therefore provided for the inner-most lane, adjacent to the highway median.

The flow-through lane is separated from the toll plaza lanes by a 3.5 metre wide shy-distance which is developed using highway tapers, and includes a barrier.

After clearing the toll area, the two toll plaza lanes merge to one lane, and the flow-through lane is tapered back adjacent to this lane to return to a two-lane cross section per direction.

7.2 Safety Considerations

The toll plaza treatment concept proposed by MHC provides a relatively sophisticated solution with a high level of safety and driver comfort:

- For flow-through traffic, there is no interruption to service, and there is physical separation with shy distance and a barrier to the toll booth and ACM facilities.
- For the toll plaza traffic, there is no drop in highway capacity, and no interference from high-speed flow-through vehicles
- For the toll booth attendants, there is no need to encroach on to the highway, and the toll plazas for each highway direction face each other across the median, allowing circulation between the plazas without affecting highway traffic

7.3 Alternatives

Whereas the MHC proposed design provides good safety features, the following alternatives may also be considered and evaluated to further enhance safety:

- Rather than developing the flow-through high-speed lane as a right-side diverge movement from the mainline, consider "splitting" the two mainline lanes into a high-speed lane (the right lane) and a toll plaza lane (the left-lane) The second toll plaza lane can then be developed as a left-side diverge off the toll plaza mainline lane.

The safety advantages of this alternative are that

- the high-speed flow through traffic would not need to diverge off the mainline to clear the toll area. Flow-through traffic simply stays in the right lane.

- the only diverge movement occurs at very low speed within the toll plaza area
- a symmetry is established between the diverge and merge areas (the toll booth lane is the one to diverge from and merge back into left mainline lane)

To achieve this configuration, the centreline of the highway may need to be shifted to the outside (using a gradual horizontal curve) upstream of the toll plaza to retain the required median width between the opposing flow directions at the plaza

- The shoulder widths which are indicated on the functional design drawings for the toll plaza section may need to be reviewed. A total clearance of 4.6 metres is provided between the ACM lane and the barrier providing separation from the flow-through lane. However, a total clearance of only 1.0 metres is provided between the flow-through lane and this barrier. As well, the outside shoulder width of the flow-through lane is reduced from 3.0 to 2.5 metres in the toll plaza section. Although a wide (4.8 metre) flow-through lane is provided, consideration may be given to providing wider shoulders for the flow-through lane, since speeds in this lane will be high, a high proportion of users will be large trucks, and to allow continued throughput in the case of a vehicle breakdown.
- As a long-term consideration, it may be desirable to make allowance for the future provision of two high-speed flow through lanes. It is likely that future technology will equip most vehicles with AVI/ETC capability, and the demand for the flow-through service may in the long term exceed single lane capacity.

Signing of the toll plaza section needs to be carefully considered and addressed. This was previously discussed in Section 6 of this report.

7.4 Toll Stations on Entry/Exit Loops and Ramps

The tolling concept proposed by MHC includes toll stations on selected highway entry and exit loops and ramps. In finalizing the design of these stations, it is important to take the following into consideration:

- Provide the maximum visibility possible. Avoid placing the toll station on curve sections or vertical grades. Make use of tangent and level sections whenever possible.
- Maximize the available queuing and storage distance, without affecting the operations of the loop or ramp, the highway, or the connecting arterial.
- Avoid configurations where vehicles may need to back up. Provide the change machine and the toll machine at a single location.
- Whenever possible, provide pull-outs for users of the toll machines, so that AVI/ETC vehicles are not unnecessarily delayed on the loops and ramps.

As discussed in Section 6, signing on the approaches to the loop/ramp toll stations (both from the highway and the connecting arterial) is important to warn drivers of the impending need to stop.

8.0 OTHER ISSUES

8.1 Speed Limit

The design criteria require that sections of the highway which have already been built or designed meet a 110 kilometres per hour design standard, while new sections should meet a 120 kilometres per hour design standard. All of the highway will be posted at a speed limit of 110 kilometres per hour.

This variance in the design speed will result in the highway providing varying "margins of safety". Sections which are designed at 120 km/h will provide cues to the driver that a certain safety margin exists between the posted and design speed. This safety margin will be reduced along sections which are designed at 110 km/h. Analytical tools are now available to quantify this relative loss in safety.

Given the design speeds which are being discussed (110 and 120 km/h), this issue does not raise significant safety concerns, since both these design speeds generally provide an excellent driving environment.

However, it would be desirable if the critical safety features of the highway were designed (or revised) to be consistent throughout with the higher design speed requirements. These features could include energy-absorbing devices (barriers and guard rails), side-slopes and the clear zone. It is therefore recommended that the New Brunswick Department of Transportation and MHC seek cost effective opportunities to upgrade the safety features of the 110 km/h design speed sections to be consistent with the 120 km/h design speed sections.

8.2 Cross-overs

Cross-overs need to be provided to allow emergency and maintenance vehicles the ability to reverse direction on the highway. However, on a toll facility, there may be an increased potential for unauthorized use of cross-overs to avoid passing through a toll plaza.

This may result in a higher risk of high-speed rear-end and merging crashes. The design and signing of the cross-overs should therefore clearly discourage unauthorized use while maintaining emergency and maintenance vehicles access.

8.3 Illumination

From a safety perspective, increasing the amount of light at interchanges is desirable. The design criteria require illumination at the interchanges, with a higher level of illumination at the four "major" interchanges and lesser illumination at the other interchanges. It is not unusual for different interchanges to be illuminated at different levels, to account for variations in complexity and expected traffic volumes.

However, it is recommended that the illumination standards required by the design criteria at "regular" interchanges be reviewed by an electrical engineer for comparison with the latest standards from TAC, other provinces, and the United States. If the design criteria illumination standards are found to be consistently lower than other standards, the New Brunswick Department of Transportation and MHC may give consideration to examining the added value of upgrading the illumination requirements.

At the detailed design stage, the location of illumination poles relative to the clear zone should be reviewed in detail, including the provision of breakaway poles and barrier protection. Breakaway poles near horizontal curves may create an added hazard, and this should be taken into consideration at the detailed design safety review stage.

8.4 Weather Warning and Control Devices

Some sections of the highway may be exposed to a relatively high frequency of fog or poor visibility conditions. The low-lying areas near the Saint John River crossing may be particularly susceptible to such conditions. Other sections of the highway may also be susceptible to snow drifts and high winds.

It is recommended that local weather experts be consulted on the potential for these conditions, and that consideration be given to providing counter-measures where appropriate. The counter-measures could include:

- Advanced Weather (and Fog) Warning Systems which automatically sense poor driving conditions and warn drivers to adjust driving behaviour.
- Wind Barriers and Snow Fences

If these features are not incorporated into the design, it is recommended that weather conditions on the highway be monitored upon opening to determine the need for these counter-measures.

8.5 Value Engineering Implications

The design criteria and the functional design of the Fredericton-Moncton Highway may be subjected to a Value Engineering analysis prior to the preparation of the final design. It is recommended that the recommendations of the Value Engineering analysis be subjected to a rigorous and independent safety review. Experience has demonstrated that apparent cost savings identified by Value Engineering may be detrimental to the safety of a project, and therefore more costly when life-cycle costs are considered.

To avoid conflict between the Value Engineering recommendations and safety, it is recommended that any Value Engineering analysis conducted for this project pursue true "added value" to the project, taking into consideration all the project constraints and characteristics, rather than just immediate cost savings.

Pe DOT's Road Test of the Road Safety Audit Process

IN OUR CONTINUING SERIES OF FEATURES ON SAFETY, A PENNDOT OFFICIAL EXPLAINS HOW THE ROAD SAFETY AUDIT PROCESS ADDS VALUE IN THE FORM OF REAL SAFETY BENEFITS TO ROAD USERS IN PENNSYLVANIA.

DID YOU EVER THINK AN AUDIT could be beneficial, educational and fun? Through a pilot process that has been underway since April 1997, the Pennsylvania Department of Transportation (PennDOT) appreciates that the road safety audit (RSA) process can be that and even more.

PennDOT is utilizing a pilot to determine if the RSA process adds value, if and how it can be incorporated utilizing existing resources and if it will delay project delivery. Soon after implementation, it became obvious that the RSA process can add value in the form of real safety benefits to road users. The Pennsylvania Transportation Institute of the Pennsylvania State University conducted prior research to assist PennDOT's pilot and is evaluating the progress to determine how to effectively adapt it for use.

The process is not a radical change in project development, however, it is a change. Since change is not always well accepted, the audits were not forced into project development by demanding actions where they could create disruption or chaos. Instead, citing of potential problems was made in such a manner to test its limits.

ELEMENTS OF THE RSA

To appreciate the value and uniqueness of the RSA process, one must understand its elements. The process ensures that safety is an integral part of the project by requiring a safety analysis at critical stages of project development

[i.e., feasibility, preliminary design, final design, pre-opening (construction) and in-service phases]. Audits are conducted by a team of experts from all disciplines of highway engineering, with assistance from experts in fields of human factors, law enforcement and risk management. Audit teams are independent from those involved

with the design to ensure it remains resistant to constraints found in project development. A series of field reviews are conducted throughout project development that can identify safety concerns that routine plan reviews may not. Comprehensive checklists are used to prompt thought and include multimodal safety concerns for all road users, including pedestrians, bicyclists, trucks, buses, emergency vehicles and railroads. Audits do not evaluate the project manager as the term "audit" may imply. They evaluate the roadway's crash potential and proactively attempt to prevent crashes from occurring. Audits also attempt to anticipate potential problems based on human factors, but they are not intended to reactively resolve existing crash problems. Once the audit is complete, the audit team generates a formal audit report, and the project manager formally responds with actions taken or why actions were not taken.

RSA PROCESS

Agencies should utilize the strengths of their organization in determining how to adapt the process. PennDOT adapted a procedure similar to Australia's.

1. Achieve management commitment, or "buy-in," to allow the process to succeed by having support when time and money are jeopardized. The process distracts normal project development by adding reviews that result in changes, additions and/or deletions of portions of the design. This can create delays, cost overruns and conflicts if those involved do not understand, accept and prepare for the possibility for change. A willingness must exist to redesign, investigate new ideas, move outside scopes of work and possibly adjust the overall program to find funds.

2. Carefully select a coordinator and audit team. Select experienced members in the various facets of highway engi-

BY TIMOTHY R. PIEPLES

neering and add experience in key areas on a project-by-project basis and/or for the different phases

3 Select the projects to be audited The types and number of projects to audit will depend on experience with the process and the availability of human resources

4 The team reviews all background information to obtain a good understanding of the plans, scope, purpose, history and constraints. Local residents and knowledge outside the agency may be solicited to help determine the needs of all road users and stakeholders.

5. Conduct field reviews at specific stages throughout project development using detailed checklists Through interaction and brainstorming, the team of experts cite general safety concerns Solutions are not required The project manager can provide background information, especially in the early phases when plans may not be available yet

6 Draft a clear, concise report containing the safety issues that surfaced from the audit Conduct a completion meeting with the coordinator and the project manager to resolve concerns, discuss details not included in the report and identify remedial treatments

7 Resolve conflicts between those responsible for the audit and project development and incorporate the remedial treatment into the design Draft a formal response to the audit report

8 Monitor the progress and ensure that the remedial treatments are incorporated into the project

9 Repeat the procedure in the next phase or as practical

PENNDOT'S PILOT

The framework of the pilot comprised of selecting team members, selecting projects, conducting audits, documenting and communicating results, and incorporating improvements Because variations in any of these affect results, various approaches are being used and details of experiences (i.e., benefits, costs, results, effects, challenges and opportunities) are continually evaluated to form recommendations for statewide implementation Observations are being noted for the following

- Team makeup,
- Employee time,
- Project cost,
- Project delay;
- Documentation,
- Suitable types of projects,
- Suitable phases of project development,
- Control of projects,
- Conflict resolution, and
- Liability

Team makeup is an extremely important consideration in ensuring a successful RSA audit A coordinator keeps the process moving and allows it to be effective for a number of projects This requires a person with knowledge, experience and enthusiasm The pilot team consisted of five members with strong backgrounds in a combination of the needed expertise of safety, traffic engineering, risk management, accident reconstruction, design, construction, maintenance and programming disciplines of highway engineering Human-factors expertise was not available within the district, and the pilot did not seek an expert However, the team included an individual from Indiana University of Pennsylvania who associates with local schools and aging agencies Most of the recommended expertise is available within the staff, including accident reconstruction, but police officers could have been utilized if accident reconstruction expertise was not available Practical safety knowledge is a must Audits are performed in addition to and independent of the projects' routine safety reviews and determination of countermeasures for existing crash clusters, therefore, the team did not include the safety engineer An understanding of the *American Association of State Highway and Transportation Officials Roadside Design Guide*, positive guidance techniques, access management, and how and why crashes occur are valuable in determining potential problems Awareness of technology and intelligent transportation systems capabilities can assist in incorporating needs of many road users in ways that may not be readily apparent Knowledge of current standards assisted in identifying what the roadway features will look like Geomet-

ric-design specialization was valuable in relating the level of safety associated with design features PennDOT also had the opportunity to perform an audit with representatives of the Federal Highway Administration (FHWA) who provided valuable geometric-design expertise Since recommended expertise did not exist, several members were trained on the needs of pedestrians and bicyclists

The team should understand the RSA process and understand that all concerns may not be accepted, which will ensure that audits remain productive and concerns remain reasonable and prudent Using higher-level managers helps maintain credibility by adding well-rounded knowledge to determine what may and may not be feasible Expertise grew with every audit

Employee time is monitored to determine the feasibility of conducting audits internally The value added by an audit is directly proportional to the time and effort given in reviewing the plans and the site The team only meets when audits are scheduled (approximately one day per month) The project managers need time to prepare briefings, attend field views, search for solutions to concerns, redesign features, contact property owners, resubmit for required approvals, communicate with the coordinator and seek necessary funding increases (approximately three days per month) The coordinator needs time to arrange meetings and field reviews, analyze field notes, process reports, maintain communication with project managers, research possible solutions and resolve conflicts (approximately five days per month) Even though having separate audit teams reduces the time the team members spend on the RSA, a single team builds experience, improves consistency and reduces the possibility of missing similar opportunities to enhance safety twice

Project costs usually increased Costs associated with safety concerns normally were not an issue in rejecting improvements Costs resulting from early reviews were more easily absorbed, and costs resulting from later reviews usually resulted in elimination of another item Occasionally, value engineering and

constructability were discussed, and cost savings suggestions resulted.

Delay in project development is the most sensitive issue in the RSA process. It is more sensitive than costs because money can be moved or items can be eliminated to cover costs. However, a loss of time can jeopardize commitments, which adversely affects an agency's credibility. Although delays occurred, projects were not unreasonably delayed. With letting commitments, decisions to incorporate improvements that could greatly delay the project were overridden. Concerns cited later in the project development phases were more susceptible to delay and usually resulted in incorporating improvements that caused the least delay.

Documentation can range from too little to too much. An agency will need to determine the optimum level that captures all concerns, conveys needed improvements and communicates results

but does not increase tort exposure. Documenting concerns through brainstorming and achieving consensus is not easy in a van during a field review. Our team chose to videotape the entire field review, which was valuable in capturing all comments and revisiting issues.

The pilot varied the methods of reporting results to the project manager. Having no formal report may reduce the concern of tort liability, but it caused confusion. Citing specific recommendations was undesirable because it left the project owner without flexibility and created unnecessary tort liability if recommendations were not accepted, even for very valid reasons. The most welcomed method was a formal report drafted by the audit team citing only concerns, not recommendations, followed by a meeting with the coordinator and project manager to resolve concerns, discuss details not included and select remedial treatments. The report was

timely so the short windows of opportunity were not missed and information was not forgotten.

Time and care were taken in drafting the audit reports and responses. Team members were concerned with their comments creating tort liability, which initially stifled ideas during field reviews, however, the concern was squelched by demonstrating that the reports were worded carefully to convey potential needs while minimizing tort exposure.

The project managers were reluctant to draft responses until all concerns were resolved to avoid the need for follow-ups. Keeping timely documentation was difficult.

Suitable types of projects for audits were determined by initially auditing 10 projects of various types and comparing the results. Not all were well suited for an audit. Capital improvement (new construction) projects were excellent candidates. They resulted in the most successful improvements because they generally had more time available in which to redesign, had less constraints, already involved right-of-way acquisitions and had the greatest level of funding available to absorb cost increases. This is a rare opportunity to make extraordinary improvements that may provide a safe and efficient roadway for years to come.

Betterment projects (rehabilitations) also were good candidates because they generally have a broader scope of work that can incorporate improvements with only minor changes. They also have a higher level of funding that can absorb cost increases. Bridge projects involving a complete rehabilitation can benefit from an RSA.

Surface improvement projects are intended to improve ride quality and generally have little money available for additional improvements. Ironically, these generally have the most needs because motorists increase speeds without having an upgrade in speed-sensitive design features. Unless the agency will consider drastically increasing the scope of work, surface improvement projects are not good candidates for audits.

At least initially, select projects are conducive to audits by having the capability and flexibility to change so the

FHWA ACTIVITIES IN ROAD SAFETY AUDITS

By Michael F. Trentacoste, P.E. (M), Director, Office of Highway Safety, FHWA

In 1996, the FHWA sponsored an international scanning trip to New Zealand and Australia consisting of state, local, FHWA and academia representatives to RSAs. The team concluded that RSAs hold promise for maximizing safety of roadway design and operations and should, as a minimum, be piloted in this country.

In 1997, the scan trip final report (*FHWA Study Tour of Road Safety Audits—Parts 1 and 2*) was published. The report is available from ITE or can be obtained from FHWA's Office of Highway Safety Web site (<http://www.ohs.fhwa.dot.gov>) under the Safety Management Systems subject heading. Last year, FHWA and scan team members focused on marketing safety audits and solicited interest by agencies to pilot the process.

Fourteen states decided to begin to pilot RSAs in 1998. FHWA sponsored a workshop in May 1998 for participating states and the two localities interested in conducting audits: PennDOT,

which initiated audits in 1997, presented its work to date at the workshop; and Ian Appleton reported on the RSA experience in New Zealand. A report on the evaluation of the pilot RSAs should be available in 1999. A good practices guide will be developed based on the evaluation.

Approximately 25 FHWA field and headquarters staff are becoming RSA technical experts and will be available to assist states and localities with their implementation of audits. A PowerPoint presentation on RSAs and a compilation of technical resources and training courses are available from FHWA. A CD and brochure geared to decision-makers is in the works. FHWA is working with ITE to fund the development of the Road Safety Audit international Web site and will assist in providing materials for that site. FHWA also will coordinate the development of RSA training with ITE. For more information on FHWA activities, contact Paul Harker at +1 202/366-2195. ■

team is not destined for resistance. If the team has early successes, it will probably put forth more effort and vice versa.

Suitable phases of project development for audits were determined by auditing projects in various phases and comparing results. Most concerns cited in preliminary engineering were addressed. Audits initially performed in later phases resulted in fewer improvements. The defining line appears to be the completion of the environmental approval. After this point, the amount of effort needed and possibility of delaying the project for major design changes is greatly increased. Concerns cited beyond the midpoint of final design were scrutinized more closely, required acceptance of beneficial cost improvements and incorporated the most inexpensive method to alleviate the concern. Pre-opening phase audits are beneficial in determining field changes that may adversely affect safety (i.e., drainage, barriers and pavement markings).

Most agencies do not consider auditing existing roads without the benefit of a programmed construction project. It can be futile to expect that a roadway built prior to 1960 would conform to today's safety standards without the benefit of a rehabilitation project. However, an audit can produce a list of locations that can be improved systematically. The risk is that the list may be unmanageable and become a potential tort liability.

Control of projects must be maintained by the agency or else cash flow, approvals, scopes of work and commitments will become unmanageable. Some decisions based on existing circumstances may be prudent from the agency's perspective but may be misunderstood and create a loss of control if improperly exposed outside of the agency. Nonagency representatives on the audit team were not initially needed because most of the expertise was available internally; therefore, further evaluation was needed to determine if nonagency members created a loss of control. Obviously, audits did not control all decisions, especially those that may have jeopardized project completion. Some improvements were desirable but deemed not worthy of greatly delaying or losing a needed project.

Conflict resolution in citing concerns, reporting concerns and accepting remedial improvements can be the difference in the success of the RSA process. Conflicts arising during these periods are being monitored to determine how best to reach resolution. The pilot has a procedure that was set as a deliberate attempt to avoid conflicts. The team must reach consensus, and the coordinator must avoid hidden agendas so concerns cannot be labeled as self-serving, the project manager and the coordinator must mutually resolve the conflict, the district's program management committee will make final determinations relative to cost and delay, and the team must accept final decisions.

Liability is reduced by having a process that purely addresses safety concerns for all road users. However, identifying concerns that may not get adequately addressed, even for good reasons, may be damaging in future torts. Even concerns cited that will be addressed adequately in the upcoming project could be used as ammunition in torts arising from recent crashes by providing proof that the agency recognized that a problem existed. Tort exposure can be minimized through responsible documentation.

Although PennDOT is covered by statute deeming safety studies as nondiscoverable in courts, the pilot is ensuring that concerns and recommendations are not frivolous and are feasible.

BENEFITS

A core value of the Malcolm Baldrige Quality Assessment is "quality through prevention." The RSA process inherently incorporates this value into projects by proactively searching for features that may cause undesirable effects, inappropriate use of standards and changes made during value engineering and/or construction, which can create potential safety concerns and costly changes in the future. Other benefits include:

- New safety concerns that would not have been raised through routine plan reviews,
- Maximized opportunities and minimized missed opportunities to enhance safety,

- Evaluation of whether the minimum standards were sufficient,
- Communication among the disciplines on the team and learning from the collective knowledge of team members,
- A higher comfort level of project managers knowing their project is being constructively scrutinized to help them construct a safe facility, and
- Incorporating safety improvements into the design of similar projects not undergoing a formal audit.

IMPROVEMENTS

Improvements of all types resulted from the RSA process. They included improving sight distance, addition of left-turn lanes, realignment of intersection approaches, the redesign of an interchange, replacing a signalized intersection with an interchange; removal, relocation and/or combining above-ground utilities; implementing access-management techniques such as relocating, removing and/or eliminating driveways, providing a paved and protected area for inspection, weight and speed enforcement; adding positive protection and delineation for an adjacent pedestrian/bicycle trail, and modifying jughandles to accommodate trucks better and to be uniform with others on adjacent roadways.

COSTS

Costs incurred by an audit, considering only salaries and equipment, ranged from \$2,000 to \$5,000. Intangible costs also exist in the form of potential tort liability but are minimized through prudent documentation. Delays and changes were inevitable and generated costs in the form of lost time available for other duties and forcing projects' milestones off track. One redesign created a loss of credibility with property owners when it also forced undesirable changes in the acquisition of right of way.

CHALLENGES

Challenges were encountered throughout the pilot. The team was successful in incorporating needed improvements in approximately 50 percent of the

attempts to improve particular situations. This is actually quite successful considering that types and phases of projects were purposefully varied for evaluation purposes.

Busy and changing schedules of the team members make organizing audits challenging. Team members changing positions and leaving the team creates loss of experience and a new learning curve.

Plans should exist early in project development. This makes detailed reviews challenging because many design decisions have not been made yet, which requires the coordinator to keep track of numerous options, possibilities and directions.

The audit must utilize the short window of opportunity when change is easy. Decisions to incorporate improvements can be controversial and require many meetings, discussions and changes requiring time and money. On major construction projects requiring environmental approvals, changes that forced the design outside of the environmental footprint were challenged because time needed to re-evaluate the impacts could delay or jeopardize the project.

Metric plans caused difficulty and frustration when comparing design standards to field conditions. PennDOT is relatively new to metric and is proceeding through a learning curve that may have caused the team to unknowingly miss issues.

Every project has unique road users and stakeholders, making it difficult to gain input from all concerned. Having representation from local municipal officials, emergency services, transit agencies, businesses and interest groups is desirable but unmanageable.

FUTURE PLANS

Future plans for PennDOT's pilot include using new methods to become more familiar and proficient at determining how to best integrate safety into roadway construction projects. The pilot also will consist of audits performed by teams of experts outside of the district, but within PennDOT, to determine if a totally unfamiliar perspective would be beneficial. Police officers and other nonagency representatives will be used as resources to determine if operational knowledge can be acquired without problems with hidden agendas or adversely affecting project development and control. FHWA's *Older Driver Handbook* will be incorporated into the checklists and nighttime field reviews will be considered. Also, PennDOT will strive to determine the most feasible methods to obtain the needs of all road users. As for an audit being fun, you will have to try it for yourself.

SUMMARY

PennDOT has developed an awareness and appreciation for the RSA process as a

cost-effective tool within existing resources that can maximize the safety potential of roadway construction projects through prudent use of the following:

- A series of safety analyses and field reviews to maximize opportunities to improve safety,
- Interdisciplinary experience to brainstorm possible problems,
- Human factors and multimodal considerations to ensure a safe roadway for all road users,
- Checklists to surface safety concerns, and
- Learning from the experiences—both successes and nonsuccesses ■



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PennDOT's ROAD TEST of the ROAD SAFETY AUDIT PROCESS

By Timothy R Pieples, P E

FORWARD

This report details the experiences of the Coordinator of the Road Safety Audit Process Pilot in Engineering District 10 of the Pennsylvania Department of Transportation (PennDOT), and may assist others to determine if and how the process should be considered for use. PennDOT began a pilot project in April 1997, to determine if and how the Road Safety Audit Process should be incorporated into the development of roadway construction projects in Pennsylvania. The goal of the pilot was to determine the following:

- 1) Does the Road Safety Audit Process add value?
- 2) Can the Road Safety Audit Process be implemented utilizing existing resources?
- 3) Will the Road Safety Audit Process delay project delivery?

Two of PennDOT's eleven Engineering Districts utilized research compiled by the Pennsylvania Transportation Institute of the Pennsylvania State University, under contract from PennDOT, to become familiar with the Road Safety Audit Process. The Districts separately adapted the process to suit the structure of their organization.

Although new experiences are still being documented, PennDOT's Road Safety Audit Process Pilot is complete. The Pennsylvania Transportation Institute evaluated the pilot project and prepared a report of the experiences from both districts. An ending meeting was conducted in December 1998, to discuss the incorporation of the Road Safety Audit Process throughout all of PennDOT. It was decided to provide all Project Managers in every Engineering District with the Road Safety Audit Checklists and that Road Safety Audit Teams will initially conduct a limited number of audits. Each Engineering District will structure the audit process to utilize the strengths of their organization, given the limited available resources. Consultant engineering firms may be considered on a district-by-district basis after each District has had exposure to the process and is able to determine the potential of Road Safety Audits.

PennDOT's District 10 aggressively participated in the pilot project by performing many audits throughout 1997 and 1998. Preplanning was performed to ensure that the pilot would provide valuable information. The framework of the audit process for the pilot comprised of selecting team(s) members, selecting projects, conducting audits, documenting and communicating results, and incorporating improvements. Because variations in any of these affect results, various approaches were used as the audits were conducted. Details of experiences, i.e., results, effects, benefits, costs, and challenges/opportunities are continually being observed and used to form recommendations for statewide implementation. The costs incurred, benefits gained, opportunities afforded, and noteworthy observations made during the audits were continually evaluated and closely monitored with special focus on the following issues:

- Team make-up
- Employee time
- Project cost
- Project delay
- Documentation

- Suitable types of projects
- Suitable phases of project development
- Control of projects
- Conflict resolution
- Liability

Recommendations have also been developed using the experiences of the year and one half long Pilot Project. Soon after implementation, it became obvious that Road Safety Audits added value in the form of real safety benefits to road users. This detailed evaluation was completed to help determine how to effectively adapt the process.

KEY ELEMENTS

It may be very easy for an agency to initially assume that they have no need for a Road Safety Audit Process or that they already are performing this process. To fully appreciate the value and uniqueness of the Road Safety Audit Process, one must understand its key elements as it has been utilized in other countries, such as Australia, New Zealand, and Canada.

- The needs of all road users, not just automobiles, are considered in the Road Safety Audit Process. Emphasis is given to pedestrians, bicyclists, large trucks, buses, emergency vehicles, and railroads.
- The Road Safety Audit Process has access to the design continually through project development. The ideal Road Safety Audit consists of five separate and formal reviews: one review during the feasibility, preliminary design, final design, pre-opening (construction), and in-service phases. This allows safety to be a more integral part of the design of the transportation facility.
- Field views focused purely on safety issues are conducted as part of the formal reviews. A team of experts brainstorm safety concerns and recommendations during the field view. Solutions are not required.
- The Road Safety Audit Team attempts to anticipate crashes. This is a proactive approach. In fact, crash history is not normally used. An agency additionally needs to ensure that crash history and the other needed elements are integrated, with the Road Safety Audit remaining a separate process.
- The Road Safety Audit Team generates a formal report after each audit; the Project Manager formally responds by stating actions taken or why actions were not taken.

There is no ideal adaptation of the Road Safety Audit Process. It is recommended that after the process is well understood, the agency should then determine how to best implement the process utilizing the strengths of their organization.

PROCEDURE

The Road Safety Audit Process is not a radical change in project development, however, it is a change. Since change is not always well accepted, the audits were not forced into project development where they could potentially create chaos by demanding actions that could disrupt project development. Instead, citing of potential problems were made in such a manner so as to test its limits. Ground rules were developed to allow unbiased information to be gained so the Pilot would provide a true representation of what can be expected if the process is implemented and allow for better recommendations of how it should be adapted. The ground rules were as follows:

- 1) The Team must reach consensus on citing concerns,
- 2) The Coordinator must avoid hidden agendas, and
- 3) The Team must accept the decisions of the Project Manager

PennDOT's pilot initially adapted a procedure that followed closely with that of Australia. The generally accepted procedure is as follows:

Program Development...

- ✓ **Achieve management commitment, or "buy-in".** This commitment is extremely important and can allow the process to succeed by providing opportunities when time and money may be jeopardized. There must be willingness to redesign, investigate new ideas, move outside the scope of work, and most importantly, to adjust the agency's overall program to find funds.
- ✓ **Carefully select audit team(s).** Experienced team members in the various facets of highway engineering is the most important key element of the Road Safety Audit. Additional members with experience in key areas should be added as needed on a project by project basis. Additional key members may even assist at different phases in project development, e.g., a geometric design expert in the preliminary design phase or a work zone traffic control expert in the pre-opening phase.
- ✓ **Select the projects to be audited.** The Road Safety Audit Process may not be suitable for all types of projects and the number of projects to audit will depend on the availability of human resources. Experience with the process will help with this determination.

Beginning the Audits...

- ✓ **Review all of the available background information.** The Team should obtain a good understanding of the project's plans, scope, purpose, history and constraints.
- ✓ **Conduct field reviews at specific stages throughout project development using detailed checklists.** The detailed checklists are reviewed and completed to stimulate thought and ensure that all safety concerns are considered. The Team must reach consensus of items that will be identified so recommendations creating conflict can be identified as an audit need, and not self-serving. Everything that the experts know, have learned, or can deduce is used to brainstorm safety concerns. Practical application of policies, standards, stakeholder needs, and most important, experience, drives the audits.

- ✓ ***Draft a formal report of findings.*** A formal report that is clear, concise, and contains the safety concerns and recommendations that surfaced from the audit should be drafted in a timely manner
- ✓ ***Conduct a completion meeting.*** A meeting with the Coordinator and the project manager is held to resolve concerns, discuss details not included in the report, and discuss remedial treatments
- ✓ ***Resolve conflicts between those responsible for the design and the audit.*** Conflicting views of potential problems and/or needed countermeasures may arise and need resolved. This is when management commitment and a good understanding of the Road Safety Audit Process will assist
- ✓ ***Incorporate solutions into the design.*** All of the previous are instrumental in allowing the most important step of incorporating solutions into design to occur. Since the Road Safety Audit Team reviews a project up to five times during project development, the Team can continually monitor progress and, not only ensure incorporation into the project, but also allow for integration of successful improvements into similar projects under design
- ✓ ***The entire procedure can be repeated when the project enters into the next phase of project development.*** Experience with the process will help determine the number of audits to perform throughout a project's development. Not all projects need an audit in all five stages. Factors will include the type of project, when the initial audit was conducted, the level of detail reviewed previously, the time lapse from the previous audit, the level of team-expertise previously utilized, and the value added by the previous audit. A continual review process will monitor previous issues and any changes made since the previous audit

Various approaches in all aspects of the framework [i.e., team(s) members, selecting projects, conducting audits, documenting and communicating results, and incorporating improvements] of the pilot process were tried to determine cause and effects. The process was continually modified as the various approaches were evaluated.

SAFETY REVIEW vs. SAFETY AUDIT

Any United States agency using federal monies must perform a safety review of the project at the end of the preliminary engineering phase and final design phase of project development. These are not Road Safety Audits. Both have their unique purpose and their differences are helpful in understanding the potential value of the Road Safety Audit Process. The following identifies the differences in the generally accepted **Safety Review** Process and the **Safety Audit** Process.

Safety Review utilizes a small team with design expertise

- ✓ Safety Audit utilizes a larger team with interdisciplinary expertise

Safety Review Teams are usually involved in the design or a similar design

- ✓ Safety Audit Teams are totally removed and totally unbiased

Safety Review Teams normally do not perform a field review

- ✓ Safety Audit Teams will perform 1 to 5 field reviews on a single project Many concerns can only be discerned during a field review

Safety Review Teams review plans to ensure that all design features are in compliance with Standards

- ✓ Safety Audit Teams utilize a comprehensive Checklist that covers many design features not normally considered during the design of most projects

Safety Reviews normally do not consider Human Factors Most crashes occur because of driver error

- ✓ Safety Audit focuses on drivers' reaction to certain highway features, including improvements, and discerns problems and concerns not normally considered

Safety Review Teams normally do not consider the needs of other modes of transportation

- ✓ Safety Audit Teams consider multi-modal safety concerns, including that of pedestrians, bicycles, large trucks, motorcycles, railroads, buses, etc

Safety Reviews normally ensure that crash clusters and remedial improvements are considered This is a reactive approach to existing concerns

- ✓ Safety Audits normally do not consider crash history, but anticipate crashes This is a proactive approach to incorporating safety into roadway projects

Incorporating the Road Safety Audit Process into the Safety Review Process is an issue that was often suggested so not to add additional steps into project development Roadblocks to this can include the following

- **Timing** - Early input is vital, continual input is desirable Normally, Safety Reviews are not conducted until near the end of the preliminary design phase and again at the end of the final design phase of project development This may not be early enough in project development and may restrict incorporation of some improvements
- **Time consuming reviews** - Safety Reviews are conducted on almost all projects Auditing all projects may not be feasible considering existing human resources Downsizing the audit procedure may be needed without adversely affecting the effectiveness of the Road Safety Audit's key elements
- **Acquiring multi-modal input** - Safety Reviews do not normally consider multi-modal needs
- **Resisting project development constraints** - This may be challenging since time and money concerns are always major issues
- **Incorporating additional safety enhancements** - Normally, Safety Reviews evaluate existing features for compliance with standards and do not consider new or different approaches, which could be difficult to incorporate due to time and money constraints Also, they do not normally include field views, which provide valuable input toward attempts to maximize opportunities to enhance safety and minimize missed opportunities to enhance safety
- **Considering human factors** - This is challenging due to a lack of past emphasis and expertise, but may be able to be somewhat addressed through the use of checklists

DISTRICT PROFILE

Located in western Pennsylvania, Engineering District 10 is comprised of five counties: Armstrong, Butler, Clarion, Indiana, and Jefferson. The District covers an area of 3,569 square miles with a population of approximately 400,000. There are 3,201 road miles under the District's jurisdiction of which 283 are on the National Highway System. Most of the road miles are rural in nature. The Engineering District Office has 243 employees and has over 250 projects under design.

ROAD SAFETY AUDIT PILOT PROCEDURE

The following will provide a summary of the procedure that District 10 used in the Road Safety Audit Pilot.

Selection of Teams

A single Safety Audit Team of five members was used. The Team members consisted of the following representatives:

- ◆ Traffic Engineer
- ◆ Construction Services Engineer
- ◆ Design Project Manager
- ◆ Maintenance Program Engineer
- ◆ Risk Management Engineer
- ◆ Comprehensive Safety Coordinator (Human Factor focus)

All of the members were PennDOT District 10 employees, except for the Comprehensive Safety Coordinator, who is employed by the Indiana University of Pennsylvania and is available to assist the Department in a community relation and educational capacity. The District's Pilot utilized a Road Safety Audit Coordinator to direct the audits and document results. The District Traffic Engineer was selected as Coordinator and to provide expertise in signs, signals, markings, and safety. The Construction Services Engineer had expertise in design, traffic engineering, and construction. He is also a member of the District's Administrative Staff and the Program Management Committee. The Design Project Manager provided expertise in highway design standards, accident reconstruction, and traffic engineering. The Maintenance Program Engineer has experience in maintenance and traffic engineering. The Risk Management Engineer provided expertise in tort liability, traffic engineering, and environmental impact requirements. The Comprehensive Safety Coordinator was chosen to provide expertise in the areas of human factors and highway safety education. A preliminary meeting was held to familiarize team members with the Road Safety Audit Process.

The same team was used to review all of the projects in the Pilot. Other employees having key expertise were utilized periodically as additional resource people (e.g., bicycle/pedestrian needs in the feasibility and preliminary design phases and work zone traffic control specialization in the pre-opening phase).

Selection of Projects

The projects that were part of the Pilot were selected by the Road Safety Audit Coordinator and the Assistant District Engineer for Design. The primary consideration in the selection of the projects was to have a variety of project types currently in various phases of project development. This was done so that the effect of the audit process could be evaluated for several different types of projects. Eleven projects were chosen. This group of projects ensured that at least one project would match up with each of the different audit stages.

The eleven projects selected were as follows:

- U S 422, Armstrong County (Kittanning Bypass) – preliminary engineering phase of a Capital Project covering five miles of new construction of a four lane concrete roadway
- U S 119, Indiana County – preliminary engineering phase of a Capital Project covering 10 miles of a two lane roadway being reconstructed into four/five lanes with a median barrier, left turn lanes, and jughandles
- U S 119, Jefferson County (Jenk's Intersection) – preliminary engineering phase of a SAMI (Safety and Mobility Initiative) project covering the reconstruction of an intersection to provide a left turn lane and improve intersection geometry
- PA 66, Armstrong County (Forks Church 3R) – final design of a Betterment Project covering the redesign of six miles of rural two lane roadway with narrow shoulders and poor alignment
- U S 119, Jefferson County (Punxy South Climbing Lane) – feasibility stage of a Capital Project covering three miles of two lane reconstruction to provide a southbound truck climbing lane
- PA 56, Armstrong County (South Bend Bridge) – preliminary design of a 200 foot long Bridge Replacement Project that included reconstruction and improvement of the roadway's horizontal and vertical alignment
- U S 119, Indiana County (Marchand 3R) – final design of a Betterment Project covering three miles of rural two lane with poor horizontal and vertical alignment
- State Route 4023, Armstrong County (Tarrtown Road) – preliminary design of a Capital Project covering three miles of rural road with poor alignment and cross section, heavily traveled by large trucks
- U S 119, Indiana County (Little Mahoning 3R) – pre-opening phase of a Betterment Project covering three miles of rural road with project tasks including the realignment of several curves
- Butler County Surface Improvement Project – final design phase of a project that consists only of resurfacing various roadways throughout Butler County
- U S 22, Indiana/Cambria Counties (Gas Center) – preliminary engineering of a Capital Project covering eight miles of new four lane construction, mostly on existing alignment, including several jughandles

Overview of Audit Procedure

A full day work session was scheduled to complete each project audit. The Road Safety Audit Coordinator began by giving a brief refreshing on the Road Safety Audit Process. The Project Manager then provided information on the proposed scope of work and background issues of the project. If a consultant was used for the design, this briefing was given with a representative(s) from the consultant's design team present. After the briefing, the Road Safety Audit Team reviewed the project plans and briefly discussed possible safety and multi-modal concerns with and without the Project Manager present. The Team field viewed the site. The field views were videotaped throughout the entire review to capture the audio of the Team's discussions and the video of the roadway's features. The Team then returned to the office to discuss the issues identified. The outcome of these discussions was used for the development of a preliminary set of concerns and recommendations from the Team. After the meeting, the Coordinator met with the Project Manager to determine if the recommendations were feasible, given the project's current status, and determine what countermeasures may alleviate the cited concerns. The Coordinator developed a short (one or two page) letter to the Assistant District Engineer for Design outlining the recommendations and concerns from the audit. The completed checklists were included. Continual discussions with the Coordinator and Project Manager took place until a remedial treatment was incorporated into the project or an alternative means to mitigate the concern was agreed upon. The Project Manager was asked to respond to the Coordinator's letter. The Coordinator monitored the project to determine if and when the next audit should take place. Due to the limited timeframe of the pilot process and the need to try various methods of conducting the audits, little emphasis was placed on re-auditing any one project. Focus was on conducting many audits using many different methods.

Conduct of Field Views

The field views were conducted by having the Audit Team travel to the project site in a van. The Team drove the project limits in both directions. The Team also drove beyond the project boundaries to note features along adjacent sections and/or routes. Each run was videotaped to provide a visual record and to record spoken comments from members of the Team. No effort was made to reach consensus on issues noted during the field view. As issues were raised, they were noted and discussed in detail upon return to the office. The field view was used as a brainstorming session. The videotape was often used to revisit issues during the deliberation session at the office.

Development and Communication of Recommendations

The Team developed a preliminary set of recommendations based on their plan and field reviews. Once these preliminary recommendations were developed, the Coordinator investigated the feasibility of correcting the concerns relative to the project's status. The Coordinator developed a final set of recommendations regarding the project. These final recommendations were sent in the form of an interoffice letter to the Assistant District Engineer for Design with a copy provided to the members of the Team. The Project Manager was asked to respond to the letter with intended actions. As experience with the process progressed, only concerns were cited with no firm recommendations. A meeting was held after the audit with the Coordinator and the Project Manager to discuss the cited concerns and possible improvements.

BENEFITS

District 10 formed a quick appreciation that the Road Safety Audit Process adds value in the form of safety benefits to road users. The following is a compilation of the benefits realized throughout the Road Safety Audit Pilot.

- It helped to ensure that changes to the roadway by the designs will not compromise safety through the scrutiny of the roadways' crash potential and the projects' scope.
- Checklists with a variety of safety items for review help to maintain a safety focus.
- The audits forced Project Managers to react to safety concerns early in project development before non-safety related constraints, such as time and money, were in control of the project.
- The audits provided input with concerns of road users not normally considered in the design of most projects. These concerns became part of the scope of work, and not an afterthought when it may be too late to provide a remedial improvement.
- Approximately 50% of the cited concerns resulted in improvements beyond the existing scope of work. Although no improvement has yet been constructed and experienced traffic to determine if the improvements were beneficial, most were based on sound engineering principles and previous successes, so they should assuredly provide a higher level of safety.
- Inherently incorporates *"Quality through Prevention"* which is a core value of the Malcolm Baldrige Quality Assessment by ensuring that quality is maintained by preventing some common occurrences: 1) Undesirable effects of motorists which can create potential safety concerns and costly changes in the future; 2) Certain standards or combination of standards may be inappropriate or unnecessary and can create potential safety concerns or detract from a more viable improvement; and 3) Changes to design features made during value engineering reviews and/or construction may create safety concerns. A timely audit can ensure these occurrences are not unwary, unnoticed, or unchallenged. For example, drainage features are often compromised due to the high costs that can be saved. Drainage is one of the most important safety items in a construction project and it can also be the most expensive to correct after the fact. A timely Road Safety Audit can help minimize these occurrences. An improvement may cost a lot, but it will cost much more if you must retrofit later. It may be an inferior product, also.
- Opportunities to enhance safety were maximized and missed opportunities to enhance safety were minimized by attempting to take advantage of the project to make needed safety improvements. Additionally, several occurrences of missed opportunities to enhance safety on recently constructed projects would have been raised had those projects been audited.
- Experience gained on a project, even through a "non-success", was translated to other projects. Successful incorporation of improvements into projects prompted the Coordinator to then look for, and separately integrate, these similarly into the development of other projects not having a formal audit.

- ❑ Interdisciplinary input was valuable in citing safety concerns outside those normally cited by the present Safety Review Process. Representatives without a strong safety background raised many concerns. Through brainstorming and achieving consensus among a team of multi-disciplinary experts on many safety-related concerns, the Pilot Team Members also gained individual knowledge of the other disciplines. Information gained at every audit could be applied to other audits and day-to-day duties. The Pilot Team also had the opportunity to perform an audit with representatives of the Federal Highway Administration who provided valuable geometric design expertise that was obtained through experience with other State Agencies.
- ❑ Discerned concerns through site reviews and observing the roadway's operation. Field views occur throughout normal project development, but none focus purely on safety for all road users and allow for citing of concerns without regard of how the concerns will be corrected.
- ❑ Experienced Team members during field reviews found ways to build things cheaper. It was not uncommon for "value engineering" and "constructability" to be discussed during the field views with cost saving suggestions resulting.
- ❑ The process forced communication to occur throughout the disciplines and better informed the various work units of actions and intentions.
- ❑ Having access to the design throughout the development of a project better-enabled safety concerns to be cited by having a better understanding of the project and, simply, having more chances to scrutinize design features.
- ❑ Having access to the design throughout the development of a project better ensured that safety concerns did not get lost, removed, or changed throughout the project development.
- ❑ The process helped ensure the safest design for all road users. Often, standards only provide the minimum treatment required. This is often not enough, especially when considering a facility that should be safe and compatible for trucks, emergency vehicles, and bicycles.
- ❑ Consistency was created in many areas because the formal report was circulated throughout the agency and educated others responsible for similar designs. It also created consistency by ensuring appropriate standards are being used and by considering adjacent networks. For example, the design of jughandles was modified due to the crash experience noted in another PennDOT District.
- ❑ Most Project Managers experienced a higher level of comfort through knowing that their project(s) have been scrutinized by others. They were more assured that their design will produce the highest quality project possible and will serve all road users. The Road Safety Audit Team was also called upon for review of specific features with which a project manager was struggling. This served to assist the project manager and to encourage and build confidence in the Audit Team. However, care was taken not to use the process "as a crutch."

TYPICAL IMPROVEMENTS

A variety of improvement types resulted from the audits. Intersection improvements were the most drastic changes to the scope of work. These included basic improvements, such as a removal of earth banks to improve the available corner sight distance and an addition of left turn lanes to reduce the number of stopped vehicles on the roadway. These also included more complicated improvements, such as a realignment of the approaches to improve the vehicular movement conflicts and a redesign of an interchange to eliminate left turn movements and create driver-friendly and safer right turn movements. Major effort was given toward consideration of replacing an at-grade, signalized intersection with an interchange. The improvement ultimately was not incorporated into the construction project because of environmental and money constraints, however, the District is considering a separate future project.

The presence of fixed objects is a very common concern that arose from the audits. Focus was often on removing, relocating, and/or combining above ground utilities that posed as potential fixed object hazards, particularly where there may be an undesirable increase in vehicular speeds. This potential is best determined through field reviews focused purely on safety.

Access Management improvements, such as relocating, removing, and/or eliminating driveways were successfully incorporated into the design of projects. Since these improvements tend to be unfavorable for the affected property owners, these types of improvements were successfully incorporated when addressed early, but not without a considerable amount of effort from the Project Managers.

Two projects successfully incorporated a paved and protected area to the side of the roadway that will be utilized for weight, inspection, and speed enforcement to control adverse driver behaviors.

Jughandles were modified to include highway lighting, to be more uniform with others on adjacent roadways, and to better accommodate trucks. Also, the Road Safety Audit Team made the District consider the use of a wider median instead of median barrier through a location so as to not utilize jughandles or restrict pedestrian travel.

Other identified concerns/opportunities that resulted in design change considerations included:

- ❑ Intelligent transportation system potential in adverse weather issues
- ❑ Capacity concerns created by trucks on long, steep, single lane downgrades
- ❑ Driveway sight distance concerns for anticipated increase in speeds
- ❑ Substandard acceleration/deceleration lanes just outside project limits
- ❑ Pedestrians inability to cross a roadway when median barrier is to be placed
- ❑ Headlight glare concerns created on mainline by new frontage roads

COSTS

It is estimated that the average cost of an Audit in the pilot process was \$2,000 to \$5,000. This cost includes only salary and equipment costs from the Team using only Department employees. (Naturally, added improvements have added costs to the project development, however, this is not considered as a cost of the audit.) This is very little for the amount of success achieved. Most of the time and efforts were placed on a select few projects. Not all projects necessitated the same level of effort to conduct the audit. Given rough estimates that were made and based on a simple \$50/hour analysis, conducting an audit added between \$2,000 and \$3,000 per review, per project in salary and equipment, when conducted internally. These costs are comparable with estimates produced in the United Kingdom, Canada, and Australia. Audits conducted by an external Team, such as a consultant or another agency, were not used. However, projects utilizing consultant-engineering designs created a slightly higher audit cost of \$4,000 to \$5,000.

The Pilot also had “intangible costs” that cannot have a price tag placed on them. They were not insurmountable and were minimized through awareness. They include the following:

- Any concern that was cited may raise an issue in a lawsuit that may not have been raised if it had not been cited by the agency, itself
- Concerns that are not addressed may be considered a tort liability if it gets to the attention of a party in a future lawsuit
- Delays and changes were inevitable and generated costs in the form of lost time available for other duties. One redesign created a loss of credibility with property owners when it also forced undesirable, additional right-of-way acquisitions. Property owners were told that their property would not be affected by the project and the audit created a change in the design and a need to acquire some of their property. This created distrust. Property owners do not appreciate nor understand that changes in design occur, let alone ones that affect them personally. Credibility is very important to an agency.
- Redesigns caused the timing of the projects' milestones to become off-track. No different than any other change, the audits created many unplanned changes. However, after the pilot began, many Project Managers began to anticipate the possibility of changes. The key is to start early to minimize conflicts associated with letting dates, completion dates, and commitments.

CHALLENGES and OPPORTUNITIES

Because the Road Safety Audit Process is a new concept to PennDOT and to most of the United States, and because the process involves time, money, work, and change, problems were expected and problems occurred. Problems occurred in several of the methods used when varying the framework of the pilot. Problems also occurred in the form of failed attempts, or “non-successes”, to incorporate needed improvements. However, the pilot was structured to accept the problems and/or failures, learn from them, and use them as opportunities to improve the process and other projects. Some may reason that since not all of the cited concerns were accepted, senior management will not allow the process to control the delivery of roadway construction projects but will only allow it to work when convenient. This was not true. However, even if it were, so what! Many improvements resulted at a small cost along with opportunities to apply the experiences of the non-successes on other similar project where existing conditions may permit incorporation. This is not failure, but an opportunity to improve the overall roadway system. Well acclaimed scientist, Louis Pasteur is quoted as saying *“I learn more from my failures than from my successes”*. This quote is most appropriate when concerns that were raised did not result in incorporating improvements. The pilot accepted these non-successes and analyzed them to help provide information in determining how to best adapt the process.

The challenges and opportunities include the following

- ❑ Numerous concerns were challenged because the audit was conducted late in project development after many decisions were made and the project advanced
- ❑ The Road Safety Audit Process requires a considerable amount of the Coordinator's time. Since the Coordinator's time and benefits gained were found to be directly proportional, maintaining aggressiveness was difficult
- ❑ High level managers participating on the team created successful audits, however, their busy schedules constantly changed, often by others and beyond their control. Organizing and postponing field reviews created frustration
- ❑ Team members changing positions was also experienced. This required a new learning curve for the replacement member and caused a loss of experience for the Team
- ❑ Usually no plans existed early in project development when it was best to begin an audit. This made a detailed review more difficult because some features and design decisions were not yet made and there was no foundation on which to begin. This also required the Coordinator to track numerous options, possibilities, and directions
- ❑ It was found that there is a very short window of opportunity when change was, somewhat, easy. When the initial review was during a later phase, difficulties with design changes occurred and selling was difficult. Because of many futile experiences, the Pilot eliminated reviews during later phases when there had been no initial review early in the project development phase

- ❑ Recommended changes that forced the scope of the design outside of the environmental footprint were challenged (and not incorporated) because time needed to reevaluate environmental impacts may have delayed or even jeopardized the project
- ❑ The Safety Audit Team received some of the same pressures from the constraints often experienced in normal project development, such as money and time
- ❑ Decisions to incorporate improvements were, at times, controversial and required many meetings, discussions, and changes. This required time and cost money, especially when consultant design was utilized
- ❑ The Coordinator spent a lot of time determining the best way to state concerns due to fear of tort liability. The Project Managers had even a more difficult time trying to draft responses to the formal reports. It was difficult to determine when the completed formal response should be drafted. This is due to the dynamic process that does not occur synchronously for the various concerns. Some are resolved quickly, and some slowly. There is no convenient time to respond and be assured that addenda will not be needed and tort liability will not be created. Several issues were not accepted due to environmental issues but were later resolved after the response was drafted
- ❑ Unnecessary work occurred through a lack of timely communication. A project had a major down scoping occur for fiscal reasons. Because the Coordinator was unaware of this change, an unnecessary and futile field review occurred. In another project, the Coordinator also performed research unnecessarily to sell a concern when the change was already accepted
- ❑ Metric plans created frustration (Pennsylvania is relatively new to metrication and is proceeding through a major learning curve). Although most Designers and Project Managers are familiar with metric designs, many other disciplines are not, causing frustration and making it difficult and cumbersome to compare design standards to field conditions. Also, issues may have been inadvertently overlooked due to unfamiliarity. The Team was made up of "old dogs" that are trying to learn "new tricks."
- ❑ Every project had unique road users and stakeholders. It was difficult to gain input from all concerned. Having a representative from all local municipal officials, emergency services, transit agencies, businesses, and interest groups on the Road Safety Audit Team is desirable but was unmanageable (PennDOT occasionally utilizes Community Advisory Committees to gather concerns in selected projects, however, the enormous amount of time required for this made it impractical for all Road Safety Audits. Therefore, the Team acted in the interest of all road users through using their experience and discussing issues with appropriate non-agency members.)
- ❑ Too many people involved in an audit made reaching consensus challenging and, at times, stifled issues because consensus could not be reached
- ❑ The Pilot was successful in only approximately 50% of attempts to improve particular situations. Mostly because late changes can be difficult to incorporate and still remain

on time and budget and, for evaluation purposes, the types and phases of projects that were audited were varied which disadvantaged many attempts from the start

□ Maintaining “Buy-In” throughout the Pilot was often challenging. Many issues scrutinized by the team were closely reviewed previously through the normal project development. This was occasionally looked upon as potentially destructive by considering going backwards in project development. This was minimized by limiting dialogue with those involved with the design to only necessary communication. Also, because many issues raised by the audits were also raised through the normal development, lengthy audits rose questions as to the “value added” by the audit process. This can be minimized through experience with the audit process by selecting projects and project phases more conducive to the audit process having less repetition of that in the agency’s routine project development. In addition, many representatives throughout the Design Section of the Engineering District Office were reluctant to accept another procedure within the busy and structured project development. However, those involved with the audits appreciate the benefit potential of a review focused purely on safety with a relatively limited investment of time. Gaining buy-in from the other Engineering Districts was extremely challenging. Sufficient briefings throughout the pilot, prior to discussing statewide implementation among district counterparts, was not performed which resulted in most being reluctant to accept the Road Safety Audit Process upon the first discussion due to the common fears of too much work, etc.

WHAT IS BUY-IN?

The Road Safety Audit Process is not a radical change in project development, however, it is a change. Since change is not always well accepted, it was very helpful that all involved understood and accepted the Road Safety Audit Process as a tool for enhancing the safety potential of the construction project. The Pilot discovered that audits could be conducted more smoothly through a commitment to safety when the following issues are understood by and remain acceptable to Senior Management:

- ❖ Willing to commit human resources necessary to conduct audits
- ❖ Willing to commit human resources necessary to redesign portions of the project
- ❖ Willing to commit funds necessary to incorporate improvements
- ❖ Willing to adjust programs to find funds necessary to incorporate improvements
- ❖ Willing to investigate new ideas
- ❖ Willing to move outside the scope of work

The Pilot discovered that audits could be conducted more smoothly if the following issues are understood by and remain acceptable to the Road Safety Audit Team:

- ❖ Some time must be devoted
- ❖ Audits are not the ultimate authority, and are used as a tool to identify safety needs*
- ❖ The District has multiple needs
- ❖ Wheels may spin
- ❖ Not all concerns can be feasibly corrected
- ❖ Gaining consensus helps support cause

** The District chose to use the audit process as a **tool**, not **ultimate authority**. Some Project Managers expressed interest in ultimate authority to support issues that were deferred to money and time, however, this may have jeopardized Management buy-in.*

OBSERVATIONS

The Road Safety Audit Pilot continually evaluated ten previously mentioned factors as various methods were used in the trial-and-error procedures so that successes and non-successes would help in determining the optimum adaptation. The following highlight the noteworthy observations.

TEAM MAKE-UP: The make up of the Road Safety Audit Team was an extremely important consideration in ensuring a successful audit. The Pilot selected District representatives having backgrounds that were identified in the prior research as the disciplines most needed for Road Safety Audits. The pilot team consisted of five members with strong backgrounds in safety, traffic engineering, risk management, accident reconstruction, design, construction, maintenance, and programming disciplines of highway engineering. All members had a variety of the needed expertise. Human factors expertise was not available within the District and the Pilot did not seek an expert. However, the Team included an individual from Indiana University of Pennsylvania who associates daily with the local schools and aging agencies. Police officers could have been utilized if accident reconstruction expertise was not available. However, the need for this expertise was not felt to be as instrumental as were the others. Their knowledge of the operational concerns of the roadway is very useful and having them as a resource person was helpful. Since the Road Safety Audit Process is to be independent of the routine safety reviews, the Pilot Team did not include the Safety Engineer. Successful audits were conducted without this expertise. Additionally, it is very beneficial that Road Safety Audits are conducted as an added level of safety that focus on less obvious and traditional design features.

Naturally, knowledge of safety is a must. Understanding the AASHTO Roadside Design Guide, positive guidance techniques, and how and why crashes occur were very valuable skills in determining potential problems. Knowledge of current standards assisted in quickly identifying to the team what the roadway features will look like. Geometric design expertise helped in relating the relative safety associated with the various design features.

The entire Team must thoroughly understand the Road Safety Audit Process and accept the bad with the good. Not all concerns may be accepted. Understanding the process is necessary so the field reviews will remain productive and concerns raised remain reasonable and prudent. Having at least one high level manager assisted in maintaining credibility by adding well-rounded knowledge of the agency and, therefore, helped determine what may be feasible and what may not.

The Road Safety Audit Process needs a person that fully understands and embraces the process to be the Coordinator. When the Coordinator is inactive, so is the Team, and so are opportunities for improving safety. An aggressive Coordinator can greatly help in monitoring recommendations, auditing more projects, and staying in constant contact with Project Managers.

Separate Road Safety Audit Teams reduces the amount of time of the team members and allows specific expertise to be utilized for appropriate projects. Maintaining the same team throughout the process builds expertise, provides

consistency from project to project, reduces the possibility of making the same mistake twice, and reduces the possibility of missing the same opportunity to enhance safety twice

The Pilot Team occasionally had additional members attend plan and field reviews to provide specific expertise. A large group made reaching consensus and maintaining focus very challenging.

Non-agency members may also provide valuable information, however, there is a risk of losing control of the project by potentially allowing unfavorable information outside of the agency. It may be better to search for the needed information offered by others through other formats. An agency may not have all of the recommended expertise, therefore, training may be necessary. Training in the needs of pedestrian and bicyclists was provided to several members.

As team members change, so will the training needs. In time, expertise will build. The Team also must buy-in to the Road Safety Audit Process by understanding the process and their role.

EMPLOYEE TIME: The Team met when reviews were scheduled. This was approximately one day per month. The Project Managers that had a project subjected to a Road Safety Audit needed time for preparing briefings, attending field views, searching for solutions to concerns, redesigning features, contacting property owners, resubmitting for required approvals, communicating with the Coordinator, and seeking necessary funding increases. This was approximately three days per month. The Coordinator needed time for arranging meetings and field reviews, analyzing field notes, processing reports, communicating with designers, and researching possible solutions to concerns. This consumed approximately five days per month for ten separate audits.

Time and effort are directly proportional to the value added and quality of an audit. That is, the more time and attention to details given to the plan and field reviews, the greater the number of safety concerns that are identified, and vice versa. If the Team had early successes which gave the team confidence and enthusiasm. If the Team was given projects that were destined for failure, i.e., too late in the project development or already over budget, or if their concerns were not taken seriously, it is felt that future audits might have been less thorough.

A single audit required from one day to two weeks to complete and varied on the complexity of the project, thoroughness of the Audit Team's understanding of the project, and level of detail in reporting concerns. Most audits were performed in two days, however, the Coordinator had to acquire additional information to help with final determinations that prolonged the audit process in two audits.

COSTS: Most of the improvements incorporated into projects resulting from Road Safety Audit Reviews involved extra work and resulted in additional costs. Additional costs were never an issue in rejecting an improvement. The costs associated with safety concerns were generally accepted. Cost was a reason for not incorporating an

improvement only when the recommendations cited were well beyond the scope of the project (DELAY seems to be more of a constraint)

Initial audits are more time consuming and, therefore, slightly more costly due to the time needed to become familiar with the project. Subsequent audits were somewhat lower in cost to conduct. The cost of audits were somewhat higher when initial reviews were made during a later phase due to the amount of time needed to gain support for a change at the later date.

Not all projects necessitated the same level of effort to conduct the audit. Given rough estimates that were made and based on a simple \$50/hour analysis, an audit adds between \$2,000 and \$3,000 per review per project in salary and equipment. These costs are comparable with estimates produced in the United Kingdom, Canada, and Australia. Audits conducted by an external Team, such as a consultant or another agency, were not used.

DELAY: The Pilot was well accepted by most involved. Most knew delays may occur and was part of buying into this "safety improvement" Audit Process. Concerns cited later in the project development phases delayed the design, however, no project missed a letting due to redesigns. These concerns usually resulted in incorporating the improvement that will cause the least delay. A Capital Improvement Project underwent major redesigns and was in jeopardy of missing a major commitment because of concerns that were raised. But because the concerns were valid safety concerns, the District underwent major efforts necessary to incorporate the changes. For most audits, delays occurred, however, projects were not unreasonably delayed because letting commitments over-rode decisions to incorporate improvements that would greatly delay the project. Because these concerns did not result in improvements does not suggest that the audit process failed. The Coordinator can utilize the knowledge to have an improvement introduced through another project at another time and the lesson learned can be utilized in another project.

Delaying projects was found to be the most sensitive issue in the Road Safety Audit Process. It is even more sensitive than money because money can be moved or items can be eliminated. Time cannot be changed and commitments reflect on an agency's credibility and are extremely important to uphold.

DOCUMENTATION: Field reviews were extremely valuable and key in citing concerns. Many things were said and discussed during field reviews. Typical brainstorming techniques were not easy to perform in a van during a moving field view. Also, many conflicts occurred that did not get resolved during the field view. Documenting everything was extremely difficult. Do you bring a secretary? Do you take the time to write all brainstorming concerns down before you move on? We chose to videotape the entire field review, including brainstorming issues. This was found to be valuable, however, it requires much of the Coordinator's time to decipher notes afterwards.

Documentation can range from too little to too much. Some Agencies utilizing the Road Safety Audit Process have produced Audit Reports that are extremely comprehensive and voluminous. An agency needs to determine the optimum level that

captures all concerns, conveys needed improvements, communicates results, but does not restrict flexibility, increase tort exposure, and create unnecessary paperwork. The pilot varied the methods of reporting results to the Project Manager. Having no formal report reduced the concern of tort liability, but it caused a lack of communication and incorporation of results in many instances. Experience with the process will determine the optimum level. The Pilot incorporated many improvements with minor documentation because the Audits were performed internally and communication was open and continual. Most reports consisted of a one or two page letter from the Coordinator to the Assistant District Engineer for Design (second only to the District Engineer in authority) and cited concerns (with limited recommendations) with the checklists available for background data.

Citing specific recommendations was found to be undesirable because it left the Project Manager with no flexibility. It may also create unnecessary tort liability on the projects where a recommendation was not accepted for even very logical reasons. A formal report citing concerns, and not recommendations, followed by a meeting with the Project Manager to resolve concerns, discuss details not included, and select remedial treatments was found to be the most welcomed method by all involved. The report needed to be timely so the short windows of opportunity were not missed and information not forgotten.

Team members were always concerned with their comments creating the potential for tort liability by documenting concerns that may not be remedied. This initially stifled ideas during field reviews, however, the concern was limited by showing that the reports can be carefully prepared and worded to minimize tort exposure and convey potential needs.

Project Managers constantly needed reminded that a formal report back to the Coordinator is required for closure. There was no optimum time to draft this response and be assured that addenda will not be needed and tort liability will not be increased. Solving the concerns is a dynamic process that does not occur synchronously for the various concerns in the audit report.

An audit team from outside of the agency was not used. The reports from an external audit team, that may have limited regard of the agency's tort liability, could potentially be damaging and serve to be counterproductive if the agency's entire program management is not considered. This is not to imply that concerns should go unstated when faced with difficult decisions, but that the preparation and wording of a report can make a big difference in the added value of an audit.

SUITABLE PROJECTS: The pilot included many of the various types of project to determine if the value added varied with project type. It was determined that the type of project has a bearing on the suitability of Road Safety Audits in the district. **Capital improvement projects** were excellent candidates for Road Safety Audits. They resulted in the most number of successful improvements because they generally had more time available in which to redesign, already involved right-of-way acquisitions, and had the greatest level of funding available to absorb cost increases. New construction projects generally have less constraints and more funding which is often a rare

opportunity to make extraordinary improvements that may provide a safe and efficient roadway for years to come PennDOT utilizes many processes throughout normal project development that are intended to identify the vast number and variety of stakeholders' needs Normal project development for larger projects may include public hearings and additional internal reviews that provide similar beneficial input that could lessen the need for, or the value added, by an audit For example, the District is presently designing some projects with the assistance of a Community Advisory Committee that is made up of many local stakeholders that provide continual input on the needs of the community and assist in project development Although concerns were still identified, efforts may have been better utilized on other projects

Rehabilitation projects are also good candidates They generally provided opportunities because the initial scope of work is already broad, already includes right-of way acquisition, and can incorporate improvements with only minor changes They have a higher level of funding that can absorb cost increases Because much of PennDOT's available funds are used to provide winter services, diligent planning was required to provide these types of projects on the major arterial roadways on a ten year cycle If you do not include needed safety improvements at the time of the project, another opportunity may be ten years away

Road Safety Audits on projects utilizing Federal Hazard Elimination Funds (**Safety Projects**) did not result in many concerns They generally included a much smaller section of roadway and had an existing emphasis on safety

Bridge reconstruction projects benefited from audits However, only the projects involving a complete rehabilitation were found to have successfully incorporated improvements because most are providing an effort to improve the alignment and roadway approaches Other than bringing some features up to current standards, projects involving only deck replacements have a very narrow scope and do not relate to features scrutinized by an audit

Surface improvement projects can be notorious for painting the road black and not looking back In other words, they are to improve ride quality and extend pavement life, and have little money available for additional improvements They are usually funded by State monies, which tend to be stretched as far as possible The Pilot found little support for major improvements Ironically, this is probably where there were the most concerns, because speeds will be increased and most design features were not improved Therefore, unless the agency will consider drastically increasing the scope of work, surface improvement projects are not good candidates for audits

Permit projects usually have no lead-time, receive little cooperation from property owners, and involve funding outside of the agency, making them very difficult to successfully audit Ironically, because little or no public money may be involved, the benefits and opportunities in an audit could be enormous But, there will be resistance from the developer with redesigns and continual reviews

SUITABLE PHASES OF PROJECT DEVELOPMENT: The Road Safety Audit Pilot audited projects in the various phases of project development and monitored the experiences and results to determine if success was dependent on the phase. It was immediately obvious that audits initially performed in a later phase were not necessarily doomed for failure, but resulted in an incorporation of a fewer number improvements. The defining line appears to be the completion of the environmental approval. After this time, the amount of effort needed for major design changes is greatly increased and often resisted.

Successfulness of the audits depended on the type of project and the phase at which cited the concern. Early audits had a much higher probability in getting concerns corrected because there is a construction project that can immediately address the need. Most concerns cited in preliminary engineering phases were addressed. Concerns cited in the later phases of projects (beyond mid point of final design) were scrutinized more closely and required cost beneficial improvements to be incorporated. If there was more than one way to address a concern, the least expensive way was selected at this point.

During Construction, or the Pre-Opening Phase, the audit was very beneficial in determining if the changes that were made in the field to the design were acceptable. Mostly changes of this nature were due to constructability problems, which left no other choice, but to make the change. The Road Safety Audit Team knows that these changes are inevitable. But, another audit in this phase can determine if there was a corresponding safety concern and attempt to compensate for the change. If it was strictly a monetary decision, which are also inevitable, the audit still allows time for the agency to weigh the potential safety concerns against the costs associated with reconstructing now, or even worse, later after the contractor is gone.

Concerns initially raised after construction started were very difficult to sell because of the numerous ramifications that are involved in late changes. These audits were beneficial in identifying concerns relating to utility locations and roadside barrier designs. Any concern first raised while the contractor has begun work will most often be very costly due to being additional work, although, it will be less expensive than after the contractor is gone. Some field construction personnel did not buy into the Road Safety Audit Process due to other numerous demanding priorities during construction. In fact, one Project Engineer stated: "Sure! As soon as you guys leave, another van load will be here to see how I'm controlling my cost overruns!"

Once the contractor is gone, the cost to improve a roadway is increased drastically and the desire to make changes decreased drastically, therefore, in-service audits were not successful. The agencies performing Road Safety Audits consider In-Service and Existing Road Reviews as a completely separate process from Road Safety Audits. Mostly because it is usually futile to expect that a roadway built prior to 1960 can feasibly conform to the safety standards of today without the benefit of a rehabilitation project. However, often a review of an existing roadway can result in a list of locations that can be improved, systematically, in a low cost manner. The risk is that the list may be long and become a potential tort liability.

CONTROL: Research of the Road Safety Audit Process indicates that various agencies prefer to have Police and other outside representatives on the team. However, unfavorable decisions based on all existing constraints and information at the time often need to be made that could be damaging and/or counterproductive if improperly exposed outside of the agency. Some non-agency personnel may have hidden agendas that may be counterproductive, also. A few issues were discussed during the pilot audits that could have been unpopular with certain interest groups/officials and may have created difficulties for the District if they were involved. (Disclaimer: Nothing criminal, unsafe, or unethical.) The fact remains that there would have been certain levels of risk of having issues become public at inopportune times causing possible loss of control of the projects' scopes and schedules. During the pilot, PennDOT remained reluctant to routinely include outside representatives as part of the core Team. This will be addressed with close attention, because of the value added by local knowledge.

The Road Safety Audit Process did not control the projects. Controversial improvements were not incorporated if delaying the letting was a possibility. This is not unacceptable even from a pure safety perspective when the overall program management is considered. The buy-in process of the audits maintained the perspective for the audit reports to be used as an additional tool for the District Engineer to help identify potential use of funding and not as "unfunded mandates." Some improvements were desirable, but were not worth delaying or losing a badly needed project. The positive perspective is that this should not be an issue if the Road Safety Audit is performed early enough in project development. If it is not, those responsible for project management will need to make a difficult decision. Furthermore, if the improvement is not accepted, the Project Manager and the Road Safety Audit Team will have learned from the experience.

CONFLICT RESOLUTION: Conflicts were expected to arise at three time frames in the Road Safety Audit Process and were monitored to provide information to determine if the process is feasible and how to best reach consensus. Conflict resolution in citing concerns, reporting concerns, and accepting remedial improvements can allow the process to succeed or fail. The pilot had a set and accepted procedure prior to beginning. The ground rules included: 1) The team must reach consensus on citing concerns, 2) The Team must avoid hidden agendas, and 3) The Team must accept the decisions of the Project Manager.

Only minor conflicts arose within the team in citing concerns and consensus was, most often, easily reached. It appears that the ground rules contributed to gaining and maintaining the necessary buy-in of the Road Safety Audit Process Pilot. When the Team consisted of more than five members, consensus was often not obtained and some concerns were not formally cited. Consensus could not be reached on a major issue in a project creating a lengthy delay in the audit process so support information could be obtained and challenged the proper method to document the concern. It also challenged some support staffs' buy-in to the Road Safety Audit Process when their recommendations were not endorsed by the Team. Ultimately, however, having the issue raised and discussed in detail appeased the staff.

Secondly, when recommendations were reported, many conflicts arose because the Project Managers could not always incorporate all improvements exactly as requested due to various reasons. When only concerns were cited and a follow-up meeting was held to resolve the concerns in the best manner feasible, conflicts were avoided. This was the most effective procedure, particularly in the later phases when time and money were most critical, because it provided flexibility in the improvement that is incorporated.

Lastly, when incorporating improvements into the project, conflicts involving money and time were the most common. Improvements that could negatively impact project development by bankrupting or seriously delaying the project were very difficult to sell to the Project Managers. The District has a Program Management Committee at the Administrative Staff level that was ready to make final determination relative to cost and delay, when necessary. Most often, conflicts were resolved through finding ways to collectively resolve the concern in a manner acceptable to the Coordinator and the Project Managers. An external audit team may make this a bit more challenging because of their increased resistance toward the constraints.

The most difficult conflicts to resolve were those that arose from audits during the pre-opening phase. The construction Project Managers also need to buy-in to the Road Safety Audit Process and are very important to its success because their field changes may unknowingly create safety concerns. Also, during construction, time is of the essence, which makes improvements requiring changes difficult to sell and incorporate. Construction Project Managers have many conflicts to resolve in order to complete projects on time and within budget at this stage, any changes must be unanimously agreed upon and cost effective.

LIABILITY: Identifying concerns that may not get adequately addressed, even for good reasons, may be damaging in future torts. Even concerns adequately addressed could be damaging in torts from crashes that occurred years ago by providing ammunition for a plaintiff that a concern exists. Having a process focused on addressing safety concerns of all varieties has to reduce tort exposure. Agencies utilizing the Road Safety Audit Process believe that everything should be well documented, however, many agencies are protected in courts. A Pennsylvania Statute that deems safety studies as "non-discoverable" protects sensitive reports. The reports during the pilot clearly included the following ***"Confidential — In-depth Safety Study. In accordance with PA Consolidated Statutes Title 75 – Vehicles (Vehicle Code) Section 3754 and 23 U S C Section 409, this safety study is confidential and the publication, reproduction, release, or discussion of these materials is prohibited without the specific written consent of the PA Department of Transportation's Office of Chief Counsel. This safety study is only provided to official agencies with official duties/responsibilities in the project development."*** However, this did not cause the Audit Team to take a shotgun approach and cite irrelevant concerns just to cite concerns. The Audit Team was prudent and responsible when raising concerns. Concerns and/or recommendations were to enhance safety, but they were feasible. (An extreme example is the Audit Team did not recommend a by-pass when the scope of work of the project is to resurface a roadway.) An irresponsible report will only serve to potentially cost the agency much-needed dollars. A report needs to be clearly thought out to prevent restricting flexibility for the Project Manager in case issues do not get resolved in a timely manner.

RECO MENDATIONS

The following is a compilation of recommendations for adaptation of the Road Safety Audit Process that are based on PennDOT District 10's experiences

- Achieve Management Commitment ("Buy-In") at all levels prior to beginning The Road Safety Audit Process can distract an agency from their normal project development routine by adding additional reviews which usually results in changes, additions, and/or deletions of portions of the design This can cause delays, cost overruns, and conflicts if those involved do not understand, accept, and prepare for the possibility for change Having buy-in at all level of project development, i e , District Engineer, Plans Engineering, Program Engineering, Designers, Road Safety Audit Team, Safety Review, and all other involved internal and external Units, helps to allow the Process to be effective
- Utilize a Coordinator to keep the process moving and allow it to be effective for a number of projects by coordinating reviews, preparing accurate comments, interacting with many Project Managers, selling safety concerns, determining adequate solutions, and resolving conflicts To effectively do all of these requires a person(s) that has knowledge, experience, and enthusiasm To effectively do all of these requires a person that has knowledge, experience, and enthusiasm Because timing is often critical to success, the Coordinator's role must be very active so communication is maintained with the Project Managers throughout the development of the projects
- The Coordinator and Project Manager should work closely but separately The Coordinator must be kept current on all projects undergoing audits through periodic and open communication Accurately advising each other (Design/Road Safety Audit) of the status and events of projects in a timely fashion can prevent " wheel spinning" from unnecessarily occurring For example, a project that was in the Pilot's Audit Process had a major down-scoping, i e , from a Betterment Project (major reconstruction) type to a Surface Improvement Project (1 1/2 " of bituminous concrete, ONLY) without the knowledge of the Coordinator, which resulted in a futile field review The Coordinator also needs to be kept current on the status of previously cited concerns
- Although, it is very important that they remain separate, so they remain excluded from normal biases and constraints
- Select an interdisciplinary team with experience Interdisciplinary knowledge ensures that safety concerns are considered from all facets of highway engineering Experience ensures a high quality review Also, Team members must be adept at visualizing planned features since plans often do not exist during audits
- Limit non-agency team members Non-agency members may provide valuable information, however, there is a great risk of losing control of the project by potentially allowing unfavorable information to get outside of the agency. Decisions were made and information revealed during the audits that could have been misconstrued and potentially damaging if not all of the facts surrounding the circumstances were known and/or understood Therefore, it may be better to search for the information offered by others through other formats Non-agency Team Members may not be a concern once the process becomes more widely accepted so non-successes are better accepted

Use can also be dependent on the agency's ability to keep control of a project during the threat of public adversity

- Provide training to team members in Human Factors, AASHTO Greenbook and Roadside Design Guide, Manual of Uniform Traffic Control Devices, Accident Reconstruction, Intelligent Transportation Systems, and Access Management. An agency may not have all of the recommended expertise, therefore, training may be a need. Training may also keep an agency from having to acquire an expert from outside. As Team members change, so will the needs to provide training. This is extremely important so the Team is as productive as possible. In time, expertise will build.
- Major reconstruction projects should include additional expertise, such as FHWA, other Agencies, other Districts/Bureaus, etc. New construction projects generally have less constraints and more funding which is often a rare opportunity to make extraordinary improvements that may provide a safe and efficient roadway for years to come. Expertise from outside the District can provide input of features and items that have and have not functioned safely in other areas and regions.
- When beginning the Audit, the Coordinator must be prepared so the team remains informed, aggressive, cooperative, and enthusiastic. The Project Manager should be at the initial review to provide the background information, especially in the early phases when plans may not yet be available. However, he/she should remain removed from discussions. Video taping the entire field review can ensure that all comments are captured and can allow the note-taker to actively participate in brainstorming. This requires work after the field reviews to decipher tape/notes, but ensures accuracy and is convenient when the team needs to revisit an issue.
- Local residents and others outside the agency should be solicited to help determine the needs of all road users and stakeholders.
- Be selective in the projects that will be audited and the number of audits performed throughout the projects' development. Development of a project may routinely include considerations in an Audit and, therefore, effort may be better spent toward another project. Also, some projects may not greatly benefit from multiple Audits throughout project development. Cost effectiveness must be balanced with the existing efforts, the risk, and the complexity of the design. Experience with the Road Safety Audit Process will help in selecting suitable projects and project phases more conducive to the audit process with less repetition of that in the agency's routine project development.
- Select projects that have the capability and flexibility to change. Do not set the Team up for failure! **And START EARLY so you can change!**
- The Road Safety Audit should be a totally separate process from the normal and routine safety review. Both processes have their specific purpose and need. District 10 did not even have the safety review committee chairman on the Road Safety Audit Pilot Team to determine if a successful safety audit could be conducted without the biases that the chairman may bring from working with the design team previously. The Road Safety Audit Process is to be independent. In addition, knowledge of crash data is

irrelevant to the audit--the team is looking for crash potential. Hopefully, and very importantly, crash history is addressed by the safety engineer working cooperatively with the design team.

- Attempt to provide your agency with confidentiality. Although Pennsylvania is no longer protected by Sovereign Immunity, it is protected by a Statute that deems "safety studies" as "non-admissible" in Torts and may keep from having to release audit reports. This is a security blanket, however, it may not be practical nor an option for some Agencies. The concern of Liability is valid, but the benefits that can be realized will outweigh the risks if care is taken when documenting the results of the audit.
- A formal report identifying the issues raised in the audit should be prepared. The report should be prepared with care and provide the formal documentation on which decisions about corrective action will be based.
- **Cite concerns not recommendations.** This is one of the most important issues learned in the Pilot. Recommendations and solutions may be too restrictive for the Design Team and could be the biggest cause for tort liability concerns if the recommendation cannot be incorporated. Reports must be carefully thought out and worded in such a way so "smoking guns" are not created by citing specific concerns that are not incorporated that may be construed as the agency being negligent in a future tort even if there is very good reasoning for not incorporating. Not wanting to create a potential liability concern was a major focus for all Team Members. Some concerns were stifled because of this. Therefore, by carefully preparing and wording the reports, Team Members will see that they are not creating a tort liability and their ideas will not be stifled.
- A follow-up meeting with the Project Manager should be held to clarify results, sell the concerns, discuss possible solutions, and discuss needed actions. This also allows an opportunity to advise the Project Manager of details that the Team may have not included in the formal report.
- The report needs to be timely so the short windows of opportunity are not missed and information is not forgotten.
- Set an acceptable protocol for resolving conflicts within the Team and with the Project Manager. The normally accepted approach is that all members of the Team must agree with a cited concern. Buy-in and an understanding of the Road Safety Audit Process helped make conflict resolution among Team Members a minor issue. To be successful, The Road Safety Audit Team, the Design Teams, the Programming Engineers, and everyone involved in the project development process must understand the Audit Process and know what to do when a conflict occurs. Having a set and accepted procedure prior to implementing the Pilot demonstrated to all parties that not everything would be completely satisfactory to everyone. Examples may include the following: 1) The team must reach consensus and the Coordinator must avoid hidden agendas so concerns cannot be labeled as self-serving, 2) The Project Manager and the Coordinator must **mutually** resolve the conflict, 3) The district's Program Management Committee (or similar committee) will make final determinations if cost

and delay may be issues, and 4) The team must accept final decisions. Not all concerns may be well accepted. It helps if everyone knows what to do if issues cannot be settled so procrastination or avoidance does not cause an issue to remain unaddressed. This concern is minimized with buy-in.

- Consider using technology to gather data, to record documentation, and to solve concerns. Try to ease the burdensome facets of the Road Safety Audit Process, like note taking, measurements, report writing, etc. to allow the Process to be less cumbersome and even fun. Videotaping was extremely helpful for the Coordinator in capturing all discussion. It was also used to revisit certain locations. Laser Measuring devices can quickly and easily measure speeds, grades, and distances that could determine, at a touch of a button, if there is a specific concern pertaining to roadway or operation of the roadway. A laptop computer can speed up note taking and especially report writing. It is important that the Team remains knowledgeable of the state-of-the-art technology that can be easily incorporated into projects to enhance safety. Examples include Intelligent Transportation System devices (Dynamic message boards for information and closed loop signal systems for congestion) and Signal Advancements (emergency vehicle preemption for EMS vehicles and queue detectors for congestion).
- If an agency has multiple districts and chooses to pilot the process in a small jurisdiction prior to wider implementation, constant communication among all to be involved needs to occur to reduce the common fears and possible misconceptions that can result in being uninformed. This will help with assist with the buy-in process.

FUTURE PLANS

PennDOT's Road Safety Audit Process Pilot is complete. However, the Pilot is now under close evaluation and PennDOT will soon incorporate the process in some form throughout Pennsylvania. An ending meeting was conducted on December 21, 1998 to discuss issues pertaining to the feasibility of statewide incorporation. The checklists will immediately be given to all Project Managers in every Engineering District and a Road Safety Audit Team, or Teams, will be formed to conduct a limited number of audits. Each Engineering District will utilize their strengths to capture the key elements of the Road Safety Audit Process to the best of their ability given the limited available resources. Consultant Engineering firms may be considered on a district by district basis after each District has the exposure to the process and determines its potential. With experience, the number of audits conducted will, hopefully, increase.

District 10 will be trying new methods and practices to become more familiar and proficient with the process and to determine methods that can further integrate safety into roadway construction projects. District 10 hopes to incorporate an audit from a team of experts outside of the district, but within PennDOT, to determine if a totally unfamiliar view would be beneficial or preferred. Police officers will also be used as resources to determine if their knowledge of the roadways' operational experience is helpful in conducting Audits. Additionally, portions of the FHWA's Older Driver Handbook will be incorporated into the checklists, nighttime reviews will be considered, and methods to determine the best feasible methods in obtaining the needs of all road users will be sought.

SU MARY

Although PennDOT's normal project development inherently incorporates safety into designs through various procedures, the Road Safety Audit Pilot created awareness and appreciation for the Road Safety Audit Process as a useful tool to maximize the safety potential of roadway construction projects through prudent use of the following

- ◆ Interdisciplinary experience to brainstorm possible problems,
- ◆ Human factors and multi-modal considerations to ensure a safe roadway for all road users,
- ◆ Checklists to surface safety concerns,
- ◆ Field reviews focused purely on safety to maximize opportunities and minimize missed opportunities to improve projects' safety potential,
- ◆ Learning from the experiences, both successes and non-successes, and
- ◆ Providing a quality project by preventing some common occurrences

Does the Road Safety Audit Process add value?

It should be no surprise that any detailed review, especially one focused purely on safety, will most likely identify safety concerns, which if corrected, will add value. The Road Safety Audit Team found potential problems associated with several types of projects in various stages of development. Efforts were made to not have the audit be influenced by the activities of the Safety Review Committee in their performance of safety reviews. The Safety Review Committee primarily addresses adherence to standards. The Road Safety Audit Team performed a different function, one that can identify issues that would not have been discovered as part of the Safety Review whereby adding safety value. It can ensure a quality product by preventing occurrences that may adversely affect safety and be costly to repair. It can also maximize opportunities to enhance safety and minimize missed opportunities to enhance safety.

With this added value, however, there is some additional risk involved as well. Does using the Road Safety Audit take the control of the project out of the hands of the Project Manager and put it into the hands of the Audit Team? Are there time problems associated with scheduling another series of meetings? What are the implications if certain concerns raised by the Audit Team are not addressed? These obstacles must be addressed through buy-in, the strengths of the individual agency, and awareness.

Can the Road Safety Audit Process be implemented within existing resources?

It is estimated that the average cost of an Audit in the pilot process is \$2,000 to \$5,000. This cost is based on an internal review Team and includes only salary and equipment costs. This cost is comparable with estimates produced in the United Kingdom and Australia and is very little for the amount of success achieved. Audits conducted by an external Team, such as a consultant or another agency, were not used. Not all projects required the same level of effort to conduct the audit and not all projects were good candidates for audits. Improvements have added costs to the project development, however, this is not considered as a cost of the audit. This is a factor that must be considered on a project-by-project basis.

Will the Road Safety Audit process delay project delivery?

The Road Safety Audit Process can delay the overall project development. The amount of delay is dependent on the type of project and the stage of the audit. For simple designs that are audited early in the development of the design, the delays are minimal and will not adversely affect project delivery. For complicated projects audited after the environmental approval or in later stages, the delays could be long and may jeopardize the letting of the project. An agency must balance the benefits derived from the audits with project commitments on an individual basis. If an agency would determine that the audit would control project development, there will be delays in delivery. However, it is most probable and prudent when considering all factors, that the agency will use the audit as a tool, act responsibly on a project-by-project basis, but will not considerably delay a project.

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Road Safety Audit: A New Too for Acc'dent Prevention

BY ITE TECHNICAL COUNCIL COMMITTEE 4S-7

During the past five years or so, various countries have adopted the practice of auditing new or existing roads for the specific purpose of accident prevention. This practice is known as road safety audit. In 1994 in response to Federal Highway Administration (FHWA) Highway Safety Program Guidelines, the Institute of Transportation Engineers proposed that American "agencies should introduce the concept of road safety audit into their systems."¹

The Institute established an international committee (ITE Technical Council Committee 4S-7 Road Safety Audits) with Kenneth W. Ogden as chair to prepare an informational report on this subject. This article summarizes the completed report.²

National Road Safety Strategies and Targets

In recent years, a number of countries (for example, United Kingdom,³ Australia,⁴ The Netherlands⁵ and New Zealand⁶) have developed national road safety strategies aimed at achieving significant reductions in road trauma and its costs.

Each of these national strategies places considerable emphasis on road and traffic engineering measures as ways of achieving the national targets. In the United Kingdom for example, at least one-third of the target reduction was to be sought from these measures.

These road and traffic engineering

measures include programs of crash reduction (that is, the development of remedial measures to apply at sites with a high crash frequency) and crash prevention (ensuring that the design of new roads is as safe as practicable, and that proactive remedial treatments are applied to existing roads).

This latter emphasis on crash prevention is a direct response to political pressures to reduce road crashes and their economic and social costs, as reflected in the development of national road safety strategies and targets. One of the key processes involved in crash prevention programs is what has become known as road safety audit.

Road Safety Audit

Road safety audit has been defined as a formal examination of an existing or future road or traffic project, or any project that interacts with road users, in which an independent, qualified examiner looks at the project's accident potential and safety performance.⁷

The objectives of road safety audit are to identify potential safety problems for road users and others affected by a road project, and to ensure that measures to eliminate or reduce the problems are considered. Safety audit aims to

- Minimize the risk and severity of road crashes that may be affected by the road project at the site or on the nearby network

- Minimize the need for remedial works after construction

- Reduce the whole-of-life costs of the project

- Improve the awareness of safe design practices by everyone involved in the planning, design, construction and maintenance of roads

Road safety audit can work in two ways: by removing preventable accident-producing elements (such as inappropriate intersection layouts) at the planning or design stages, or by mitigating the effects of remaining or existing problems by the inclusion of suitable crash-reducing features (such as anti-skid surfacing, guard fencing, traffic control devices and delineation).⁹

International Review

It is useful to briefly chart the emergence of the road safety audit concept as a discrete element of a road safety program, and to consider its introduction in several countries.

United Kingdom

The concept emerged originally in the United Kingdom in the 1980s. In 1987, the Department of Transport developed strategies aimed at reducing road casualties by one-third by the year 2000. The following year, legislation was passed that reinforced the requirement that road authorities in mainland Britain take steps to reduce the possibility of crashes on new roads. This requirement led to the preparation of

two key publications *Road Safety Code of Good Practice*¹⁰ and *Guidelines for the Safety Audit of Highways*⁸ Road safety audit was made mandatory from April 1991 for all national "trunk" roads and motorways (freeways) in the United Kingdom.

Australia

In Australia, Austroads (the national association of road and traffic agencies) has established a working party to develop road safety audit guidelines to provide a national focus for this work.¹¹ State road authorities have progressed road safety audit at different rates. In New South Wales, 20 construction projects are audited within each of the road authority's regions, 20 percent of the existing road system is to be audited each year to identify the deficiencies of the existing road and identify priorities for action. In the State of Victoria, a safety audit is conducted for all major projects, for 20 percent of other construction projects, and for 10 percent of maintenance works.

New Zealand

In New Zealand, the national roads and public transport agency (Transit New Zealand) has embraced road safety audit and began conducting pilot safety audit projects (which had a substantial training component) in 1992. From 1993, safety audit was mandatory for a 20 percent sample of state highway projects. A pilot program for road safety audit at the local government level has commenced.

United States

In the United States, road safety audit as a formalized procedure has not been introduced.¹² However, the Federal Highway Administration report "Management Approach to Highway Safety: A Compilation of Good Practices" summarizes the need for a comprehensive and coordinated approach to highway safety.¹³ Although safety audit as such is not mentioned, two of the key programs had strong undertones of this concept:

- A program for identifying, investigating, setting priorities and correcting hazardous or potentially hazardous roadway situations
- A process to consider safety needs, goals and priorities in the development and construction of all highway facilities

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) included elements related to road safety, and the FHWA/FTA Docket No. 92/14 published a proposed rule on safety management systems within the *Highway Safety Program Guidelines*, stating that "the highway safety management system may be further defined as management processes to ensure that all opportunities to improve safety are identified, considered, implemented where appropriate and evaluated."¹⁴

ITE responded to this proposed rule by submitting among other things, that "Agencies should introduce the concept of the safety audit into their systems."¹

Application of Road Safety Audit

Road safety audit may be carried out at any or all of several stages of a project. These include the following:

Stage 1: Feasibility

As an input to the feasibility stage of a scheme, a safety audit can influence the scope of a project, route choice, selection of design standard, impact on the existing road network, route continuity, provision of interchanges or intersections, access control, number of lanes, route terminals, stage development, and more.

Stage 2: Layout or Preliminary Design

This audit stage is undertaken on completion of draft plans or a preliminary design. Typical considerations include horizontal and vertical alignment, sightlines, intersection layouts, lane and shoulder width, pavement crossfall and superelevation, overtaking lanes, provision for parked and stationary vehicles, provision for cyclists and pedestrians, effects of departures from standards and guidelines, safety during construction, and so on. After this stage, as land acquisition becomes finalized, subsequent significant changes in road alignment become harder to achieve.

Stage 3: Detailed Design

This audit stage occurs upon completion of detailed design, but normally before the preparation of contract documents. Typical considerations include line markings, signing, delin-

eration, lighting, intersection details, clearances to roadside objects, provision for road user groups with special requirements (for instance, pedestrians, cyclists, people with disabilities, trucks and buses), temporary traffic management and control during construction, drainage, poles and other

roadside objects, landscaping, barriers and guard fencing

Stage 4: Preopening

Immediately before the opening of a scheme to traffic, the audit would involve driving, riding and walking through the project to check that the safety needs of all road users are adequate. This should involve a night-time inspection and, if possible, an inspection in both wet and dry conditions. It would canvas similar issues to those raised in Stages 2 and 3, but with a view to assessing their adequacy as actually constructed, taking particular note of variations that might have occurred from the plans in the course of construction.

Stage 5: In-service

This stage involves a systematic examination of sections of the existing road network to assess the adequacy of the road, intersections, road furniture, the roadside, and so on from an explicit safety viewpoint. This can have two

applications: monitoring a new scheme after it is opened to traffic (in the weeks and months following a Stage 4 audit), or a safety audit of an existing road or road network with a view to identifying safety-related deficiencies. The audit of existing roads and road networks is discussed later.

Safety Audit Process

While each road agency undertaking a road safety audit may have its own audit process, there are several key requirements¹⁵

Commitment

Whether road safety audit lives up to its potential depends largely upon the commitment and endeavors of the organization and staff involved. It is vital that it be seen as an integral part of an agency's overall program. Otherwise, it runs the risk of being perceived as questioning the competence and professionalism of the designer or road builder.



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Process

The road safety audit process must seek to take an overall view of safety. The process aims to reduce the whole life cost of a scheme. Although there will be costs of the audit process, these must be offset against the potential for savings elsewhere. The savings may be from timely alteration to plans (it is much cheaper to change a detail on a plan than to replace or remove a feature once installed), from subsequent crash prevention, and from reductions in the costs resulting from litigation. Experience in those jurisdictions where it has been introduced indicates that safety is now a more explicit factor in all levels of road decision-making, rather than a minor or implicit consideration as previously may have been the case.

Organization

There are a number of ways in which the safety audit process may be carried out. These include

- Specialist advice and audit team

- Specialist advice and independent project manager.
- Specialist advice to the designer.
- Second design team and independent assessor.
- Second design team auditing.
- Own team auditing.⁸

An agency developing a road safety audit process will need to determine which of these procedures (or an alternative) to follow, depending upon its own "culture," expertise and the role of safety auditing within a wider institutional framework. Whichever method is adopted, the key factors are the same.

- The audit team must include specialist knowledge of safety engineering.
- The findings of the audit should be documented and reported formally at each stage of the audit process.
- The reasons for various elements of audit advice should be documented formally.
- The reasons for rejecting any ele-

ment of advice should be explained to the scheme designer.

- Provisions for arbitration should be made.
- Independence of audit must be maintained, and there should be an awareness of possible litigation if there are subsequent failures.¹⁶

Checklist

The actual tasks undertaken by a safety audit team will in most cases involve the use of checklists or prompts. These typically show the sorts of issues and problems that can arise at the relevant stage of the project. Examples are presented as inserts in the IHT and Austroads guidelines for a wide range of applications and project stages.^{8,11} A number of PC-based programs containing checklists or prompts are now coming on the market, and these will help facilitate the audit process.

Important to remember, however, is that these checklists or prompts are

really only an *aide memoire*. Their advantage is that a formalized checking procedure, using a checklist or something similar, is less likely to overlook problems. However, they cannot be a substitute for expertise, and it is imperative that those responsible for undertaking safety audits have adequate training and experience in road safety engineering. One of the main benefits of checklists is that designers use them to audit themselves before their work gets to the auditor, thus enhancing quality at an even earlier stage.

It is also vital that the safety audit procedure involves a site visit, at whatever stage it is concerned with, since there will inevitably be factors present and identifiable at the site that are not evident from the plans.

Training and Development of Expertise

The size of the audit team will vary with the size and complexity of the pro-

ject to be audited. In the British experience, a three-person team has been found to be suitable at the feasibility and/or layout design stage. The team comprises a road safety specialist with experience in crash investigation and expertise in safety engineering principles and practice, a highway design engineer, and a person with experience in safety audit who is able to generate discussion and assist in the procedure. At the detailed design stage, it may be necessary to supplement the above team with specialists in particular areas (such as traffic control and street lighting) depending on the nature of the scheme. At the preopening and in-service stages, the inclusion of the police and an engineer who has (or will have) responsibility for the maintenance of the road and its traffic control devices is important.¹⁶

Monitoring and Evaluation

A jurisdiction introducing safety audit needs to set up a process of moni-

toring and evaluating the process. This involves three aspects

- Procedures, problems encountered, and the system's effectiveness
- Critical appraisal of the checklists and their use
- Evaluation of costs and resources by scheme type and stage¹⁶

Liability

The Australian guidelines contain an entire chapter on this aspect. This will not be summarized here, but its conclusion is relevant.

No case involving road safety audit has yet come before a court. Therefore the legal implications must be speculative, not certain. But the predictions are not guesswork; they are based upon well established principles of tort law.

Safety audits will create a safer road environment. A major aim of litigation in this area of law is to encourage safety. It follows that the use of road safety audit will be encouraged by the legal system. But the major focus of the law in this area is the end product—the state of the road itself—and not the methods by which an authority achieves this.

Roads can be made safe by a variety of methods—including black spot treatment, periodic inspection, the adoption of higher standards of engineering practice, greater allocation of funds and road safety audits. It is for highway authorities to decide which mix of these is best for any given project, and as an overall policy.

It is obvious that the process of road safety audit can play a vital part in achieving safer roads. Highway authorities that fail to adopt the process run the risk that avoidable defects on the road will not be discovered, and that the defects will cause accidents. Highway authorities that fail to adopt safety audits or comparable processes run a higher risk that legal liability will be imposed.¹¹

Audit of Existing Roads

The safety audit of existing roads has not as yet been a major component of road safety audit programs in place, although the guidelines in use in various countries often allow for its inclusion.

However, a formal program of road safety audit of existing roads can be an important component of the overall audit procedure (Stage 5 as mentioned above). For example, the Austroads guidelines state that the aim of this audit stage is "to identify any existing safety deficiencies of design, layout, and street furniture which are not consistent with the road's function. There should be consistency of standards such that the road users perception of local conditions assists safe behavior."¹¹ These guidelines suggest a different approach depending upon the length of road. For short lengths (for instance, less than 30 km), a detailed inspection is suggested, highlighting specific issues and making specific recommendations. For longer lengths, a two-part inspection is suggested, with the first being a broad assessment of the route highlighting what major problems exist and where they are located. Then only these locations are subject to the more detailed audit, as in the approach suggested for shorter lengths.

Effectiveness of Road Safety Audit

Although it is a relatively recent technique, evidence is emerging that road safety audit is a cost-effective safety measure.

There is evidence that in many

cases, existing design and construction processes allow deficient or inappropriate elements of road projects to be implemented. For example, many jurisdictions will have had experience with road safety problems that have arisen within a year or two of the opening of a new project. These problems would have been identified if the project had been subject to safety audit. A formal requirement that a project be subjected to a safety audit will thus very likely lead to improved safety. Experience in the United Kingdom suggests that for individual schemes, one-third of accidents have the potential for removal by safety audit.¹¹

Resources that need to be devoted to safety audit are in fact quite small. U.K. experience suggests that one safety auditor is required to cover an area experiencing some 2,000 casualty crashes a year (although more recent experience suggests that this may be underestimated by a factor of 2).⁸ Australian and New Zealand experience suggests that safety audit adds about 4 percent to road design costs.

There have been some attempts to quantify the benefits of road safety audit. One highway authority in Scotland has estimated that one-third of future crashes at road improvements are preventable by audit, and that a 1 percent crash saving per year—worth about £1 million (approximately

US\$15 million)—is possible across the region at a resource cost of £70,000 (approximately US\$100,000), a benefit cost ratio of 15:1.17. In New Zealand, a potential benefit cost ratio of 20:1 has been estimated for road safety audit procedures.⁷

Conclusion

Road safety audit is an emerging procedure aimed at ensuring that road authorities "get it right the first time." It is aimed at crash prevention rather than crash reduction. Audits may be undertaken at any or all of five stages: feasibility, layout design, detailed design, preopening or in-service. An agency introducing a road safety audit process must have a commitment to the process, and ensure that formal procedures are established to ensure that the audit is effective and influential. Key factors are the independence of the person or team undertaking the audit, and the accountability of the person making decisions in light of the audit team's report. Concomitantly, the auditor or audit team must be competent and experienced in road or traffic engineering, and have had adequate training in road safety audit. The educational effects of safety audit on road designers and managers will result in more safety-conscious planning and design.

It is likely that a form of road safety audit will become more common worldwide as agencies seek to minimize the whole-of-life cost of road projects, and gain a measure of protection from the costs of litigation. Certainly in those jurisdictions where it has been used, there is enthusiasm for the process based upon a conviction that it is a highly cost-effective road safety measure.

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This report is a summary of an Information Report of the Institute of Transportation Engineers. The report was prepared by Technical Council Committee 4S-7. The information in this report has been obtained from experiences of transportation engineering professional and research. ITE Informational Reports are prepared for informational purposes only and do not include Institute recommendations on the best course of action or the preferred application of data. The complete report is available from the ITE Bookstore at ITE Headquarters (IR-076, \$10/\$15).

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Checklist 1-1 General Topics

Project _____
 Audit Team Members _____
 Date _____

Item	Issues to be Considered	Check	Comments
1 Scope of project, function, traffic mix	A broad appreciation of the scope of the project will assist in addressing topics further on in this check list		
	What is the general type of project for which the design has been carried, e.g. freeway, major arterial, or a minor improvement?		
	Is the road intended to carry high speed traffic or serve local access needs only?		
	Is there a mixed function, or a potential confusion to the driver about the road's function?		
	What kind of traffic is likely, ranging from high speed mixed traffic (i.e., including a significant number of trucks) or for more general use, including bicycles and significant pedestrian traffic?		
2 Type and degree of access to property and developments	Check the general layout of the project, including		
	Questions of visibility and speed, related to the number and type of intersections and accesses to adjacent property		
3 Significant adjacent developments	Check the width of the right of way, or the detailed design within that width, as affected by access requirements		
	Check major generators of traffic and parking, including housing or shopping centers, developments that may have a significant influence on the form of the design		
	Check for distance of accesses from intersections and visibility of and from accesses to significant traffic generators		

Checklist 1-1 General Topics

Project _____
 Audit Team Members _____
 Date _____

Item	Issues to be Considered	Check	Comments
4 Influence of staging	Check the design against staging requirements		
	Will this project be one stage or several?		
	Will future projects be either linear extensions of the project, or will possible redundancies be caused by widening?		
5 Future widening and/or realignments	What is the likelihood of (a) Future widening?		
	(b) The addition of a complete second directional roadway?		
	If designed for eventual divided operation, will the interim two-way operation create problems (e.g., overtaking)?		
	(c) Later realignments?		
6 Wider network effects	(d) Introductions of major geometric changes at intersections?		
	Are there any harmful or beneficial safety aspects within the proposed project or on the surrounding network?		

Road Safety Audit Seminar

Checklist 1-2

Design Issues

Project _____

Audit Team Members _____

Date _____

Item	Issues to be Considered	Check	Comments
1 Route Choice	Consider the broad concept involved in the choice of a route or alignment.		
	Does the project follow existing roads or is it a completely new project and what are the effects of this?		
	Does the project fit in with the physical constraints of the landscape and major network considerations?		
2 Impact of continuity with existing network	Check the potential for problems where the proposed project joins the existing network		
3 Broad design standards	Check that the appropriate design standards have been used having regard to the scope of the project, and its function in relation to the traffic mix		
4 Design speed	What design vehicles are used?		
	Check the design speed for horizontal and vertical alignment, visibility, merging, weaving, and decelerations or accelerating traffic at intersections		
	Check the effects of sudden changes in the speed profile or posted speed limit		
	Check the appropriateness of both the design speed and speed limit on the proposed road project.		

Checklist 1-2

Design Issues

Project _____

Audit Team Members _____

Date _____

Item	Issues to be Considered	Check	Comments
5 Design volume and traffic characteristics	Check the appropriateness of the design for the design volume and traffic characteristics (including the effects of unusual proportions of heavy vehicles, cyclists and pedestrians, or lateral acceleration effects)		
	Check the possible effects of unforeseen or large increases in traffic volume or changes in the traffic characteristics		

Checklist 1-3

Intersections

Project _____

Audit Team Members _____

Date _____

Item	Issues to be Considered	Check	Comments
1 Number and type of intersections	Check the appropriateness of intersections with respect to the broad concept of the project, its function and traffic mix and also the need to serve intersecting roads appropriately to their function		
	Check the number and type of intersections, including the relationship both of spacing and type of one intersection with another		
	Are there any traffic or safety aspects of the project or of the traffic in the area which would favour or disfavor any particular layout?		
	Are there any physical or visibility constraints which would influence the choice or spacing of intersections?		
	Are all of the proposed intersections necessary or essential, or can the surrounding network be modified beneficially?		
	Does the vertical geometry or horizontal alignment have any influence on the style or spacing of intersections?		

Safety Audit Stage 1

Checklist 1-4

Environmental Constraints

Project _____

Audit Team Members _____

Date _____

Item	Issues to be Considered	Check	Comments
1 Safety aspects, including weather and natural features	Check the surrounding terrain for physical or vegetation defects which could affect the safety of the project - for instance, heavy planting or forestry, deep cuttings, physical features such as steep or rocky bluffs which constrain the design		
	Check the project for the effects of wind		
	Check for the effects of fog, mist or ice		
	Do the gradients, curves and general design approach fit in with the likely weather or environmental aspects of the terrain?		
	Are there scenic vistas or overlooks which may distract a driver or cause a vehicle to unexpectedly slow down or otherwise maneuver?		

Project

Audit Team Members

Date

Item	Issues to be Considered	Check	Comments
1 Safety aspects not already dealt with	Check any aspects which do not readily fall into any of the above categories, such as		
	(a) Flooding		
	(b) Moving stock		
	(c) Low flying aircraft, advertising or other matters which could be distracting to drivers		
	(d) Turn outs or parking may be needed (e.g. for tourist routes, picnic or rest areas)		
	(e) The potential of the route or site to attract roadside stalls		
	(g) Any other matter which may have a bearing on safety		

Checklist 2-1 General Topics

Project _____
 Audit Team Members _____
 Date _____

Item	Issues to be Considered	Check	Comments
1 Changes since Stage 1	Check for any major changes in principle since the Stage 1 Audit was carried out Check that the conditions for which the project was originally designed still apply, i.e., there have not been significant changes to the surrounding network or area to be served, or traffic mix		
2 Drainage	Will the new road drain adequately? Is there a possibility of surface flooding or overflowing from surrounding or intersected drains and water courses?		
3 Climatic conditions	Do weather records or local experience indicate a problem (e.g., snow, ice, wind, fog)?		
4 Landscaping	Is the landscaping design or planting likely to lead to a lowering of safety with mature or seasonal growth? (i.e., through loss of visibility, obscuring signs, shading or light effects, leaves, flowers, or seeds dropping on the highway)? Is "frangible" vegetation appropriate? Consider pedestrian visibility in particular		
5 Services	Does the design adequately deal with buried and overhead services? At this stage the location of fixed objects or furniture associated with services should be checked, including the position of poles		

Checklist 2-1 General Topics

Project _____
 Audit Team Members _____
 Date _____

Item	Issues to be Considered	Check	Comments
6 Access to property and developments	Can all accesses be used safely? Are there any downstream/upstream effects from development accesses, particularly near intersections? Check rest area accesses		
7 Emergency vehicles and access	Has provision been made for safe access by emergency vehicles and vehicles? Check the design of medians and barriers, and the ability of emergency vehicles to stop without necessarily disrupting traffic		
8 Future widening and/or realignments	If the project is only a stage towards a wider or divided roadway, is the signing and design adequate to impart this message to drivers? Is the transition from two way to divided roadway handled safely?		
9 Staging of the project	If the scheme is to be staged or constructed at different times, are the construction plans and program arranged to ensure maximum safety and do they include specific safety measures, signing, and adequate transitional geometry for any temporary arrangements?		
10 Staging of the works	If the construction of this project is to be staged or split into several contracts check that these are arranged for maximum safety		
11 Significant adjacent developments	Check that the design handles accesses to major adjacent generators of traffic and parking and developments safely Check that lighting or traffic signals on an adjacent road do not affect the drivers' perception of the road ahead		

Checklist 2-1 General Topics

Project _____
 Audit Team Members _____
 Date _____

Item	Issues to be Considered	Check	Comments
12 Stability of cut and fill	Check that the geological conditions in the country through which the road is to be constructed do not pose a significant threat to safety of vehicle occupants		
13 Maintenance	Check if maintenance vehicles can be safely located.		

Checklist 2-2

Project _____
 Audit Team Members _____
 Date _____

Item	Issues to be Considered	Check	Comments
1 Geometry of horizontal and vertical alignment	<p>Do the horizontal and vertical design of the project fit together comfortably?</p> <p>Check the design for adequacy with regard to the function of the road</p> <p>Check the possibility of drivers not being able to read the road characteristics due to visual illusions, subliminal delineation, etc. (e.g., line of trees, line of poles, etc)</p>		
2 Typical cross-sections	Are the lane widths, shoulders, medians and other cross section features in accordance with standard design or adequate for the function of the road?		
3 Effect of cross-sectional variation	<p>Check that there are no undesirable variations in cross section design</p> <p>Check cross slopes which could affect safety, particularly where sections of existing highway have been utilised, or where there have been compromises to accommodate accesses, etc</p> <p>Check where compromises have been made such as narrowing at bridge approaches or to avoid physical features</p>		
4 Roadway layout	<p>Check that total traffic management features in addition to horizontal and vertical alignment and cross section) are not likely to create unsafe conditions</p> <p>Check the layout of road markings and reflective media both on the road and on the surrounds to deal with changes in alignment, particularly where these are substandard</p>		

Checklist 2-2 Design Issues

Checklist 2-3 Alignment Details

Project _____

Audit Team Members _____

Date _____

Project _____

Audit Team Members _____

Date _____

Item	Issues to be Considered	Check	Comments
5	Check the appropriateness of the design speed and speed limit		
	What design and check vehicles are used?		
6	Check the safety aspects of shoulder provision, including the provision of sealed shoulders, the width and treatment on embankments and cross slope of shoulders		
	Are the shoulders likely to be used by slow moving vehicles or cyclists?		
	Check safety aspects of rest areas		
7	Are there any approved departures from standards or guidelines which affect safety?		
	Are there any hitherto undetected departures from standards which should be brought to the attention of the designer?		

Item	Issues to be Considered	Check	Comments
1	Are horizontal and vertical alignments consistent with the required visibility requirements?		
	Check that sight lines are not obstructed by		
	(a) Fences and crash barriers		
	(b) Boundary fences		
	(c) Street furniture		
	(d) Parking facilities		
	(e) Signs		
	(f) Landscaping		
	(g) Bridge abutments		
	Inappropriate consideration of horizontal and vertical alignment (e.g. horizontal curve just over a crest vertical curve)		
	Check that railway crossings, bridges and other hazards are conspicuous		
	Are there any other local features which affect visibility?		
	Will sight lines be obstructed by temporary features such as parked vehicles in turn outs, or by parked or queued traffic generally?		

Checklist 2-3 Alignment Details

Project _____
 Audit Team Members _____
 Date _____

Item	Issues to be Considered	Check	Comments
2 New/existing road interface	Have implications for safety at the interface been considered? Are there sudden changes in the speed profile or access or lateral acceleration characteristics?		
	Does the interface occur near any hazard, i.e., at a crest or bend or where poor visibility or distractions occur?		
	Check that the change is affected safely where roadway standards differ		
	Check transition is safe where road environment changes, for example, urban to rural, fast to slow, lit to unlit.		
	Check the need for advance warning.		
3 Readability by drivers	Will the general layout, function and broad features be recognized by drivers in adequate time?		
	Check the approach speed and general likely position of vehicles as they track through the project		

Checklist 2-4 Intersections

Project _____
 Audit Team Members _____
 Date _____

Item	Issues to be Considered	Check	Comments
1 Visibility to and visibility at intersection	Are horizontal and vertical alignments consistent with the required visibility requirements? Will drivers be aware of the presence of the intersection (especially if facing a Stop/Yield sign)?		
	Check that sight lines are not obstructed by		
	(a) Fences and crash barriers		
	(b) Boundary fences		
	(c) Street furniture		
	(d) Parking facilities		
	(e) Signs		
	(f) Landscaping		
	(g) Bridge abutments		
	Check that railway crossings, bridges and other hazards are conspicuous		
	Are there any local features which require affect visibility?		
	Will sight lines be obstructed by permanent or temporary features such as parked vehicles in turn outs, or by parked or queued traffic generally?		

Checklist 2-4

Intersections

Project _____

Audit Team Members _____

Date _____

Item	Issues to be Considered	Check	Comments
2 Layout, including appropriateness	Is the type of intersection selected (crossroad, T, roundabout, signalized, etc) appropriate for the function of the two roads?		
	Are the proposed controls (Stop, Yield, signals, etc) appropriate for the particular intersection being considered?		
	Are junction sizes appropriate for all vehicle movements?		
	Are there any unusual features which could affect road safety (e.g., cyclists, heavy truck movements, public transport operations, etc)?		
	Are the lane widths and swept paths adequate for all vehicles?		
	Are there any upstream or downstream geometric features which could affect safety, e.g., merging of lanes?		
	Will the general type, function, priority rules and broad features be recognized by drivers in adequate time		
3 Readability by drivers	Check the approach speed and general likely position of vehicles as they track through the project		

Checklist 2-5

Special Road Users

Project _____

Audit Team Members _____

Date _____

Item	Issues to be Considered	Check	Comments
1 Adjacent land	Will adjacent activity and intensity of land use have an adverse safety effect on the project? Are special measures needed?		
2 Pedestrians	Have pedestrian needs been considered?		
	If footpaths are not specifically provided, is the road layout safe for use by pedestrians, particularly at blind corners or on bridges?		
	Are pedestrian subways or footbridges sited to provide maximum use?		
	Is the avoidance of footbridges or subways possible by crossing the road at grade?		
	Has specific provision been made for pedestrian crossings, school crossings or pedestrian signals?		
	Are these sited to provide maximum use ?		
	Are pedestrian refuges / curb extensions needed?		
	Is specific provision required for special groups, e.g., the young, elderly, sick, disabled, deaf, or blind?		

Checklist 2-5

Special Road Users

Project _____

Audit Team Members _____

Date _____

Item	Issues to be Considered	Check	Comments
3 Cyclists	Have the needs of cyclists been considered, especially at intersections? Is a bicycle lane needed? Are any bikeways separate from the main roadway, of standard or adequate design? Is there a need for shared pedestrian/cycle facilities?		
4 Equestrians and stock	Where bikeways terminate at intersections or adjacent to the roadway, has the transition treatment been handled safely? Are there any needs for special bicycle facilities (e.g., bicycle signals) if not already provided?		
5 Freight	Have the needs of equestrians been considered, including the use of verges or shoulders and rules regarding the use of the roadway? Can underpass facilities be used by equestrians/stock?		
6 Public Transport	Have the needs of truck drivers been considered, including turning radii and lane widths? Have the needs of public transport users been considered? Are bus stops positioned for safety?		
7 Road maintenance vehicles	Has provision been made for road maintenance vehicles to safely be used at this site?		

Checklist 2-6

Signs and Lighting

Project _____

Audit Team Members _____

Date _____

Item	Issues to be Considered	Check	Comments
1 Lighting	Is this project to be lit? Are there difficulties of illuminating sections of the road caused by trees or overpasses, for example? Has the question of siting of lighting poles been considered as part of the general concept of the project? Are frangible or slip-base poles to be provided? Are any special needs created by ambient lighting? Are there any aspects of the provision of lighting poles which would require consideration from the safety point of view in their being struck by vehicles?		
2 Signs	Are sign structures needed? Are signs located at points to allow adequate readability? Are signs located to limit visibility from accesses and intersecting roads? Are signs appropriate to the drivers needs (e.g., destination signs, advisory speed signs, etc)? Have the safety aspects of signs been considered as part of the general concept? Are there any aspects of the provision of sign posts which would require consideration from the safety point of view in their being struck by vehicles?		
3 Marking and delineation	Check that the appropriate standard of delineation and marking has been adopted		

Checklist 2-7

Construction and Operation

Project

Audit Team Members

Date

Item	Issues to be Considered	Check	Comments
1 Buildability	Are there any features which could inhibit safe construction (e.g., through traffic, construction vehicles)?		
2 Operation	Is adequate safe access to the works available?		
3 Traffic management	Are there any factors requiring specific road safety provision, including maintenance?		
4 Network management	Are there any traffic management features which management would require special attention during construction or during the transition from construction to full operation?		

Checklist 2-8

Other Issues

Project

Audit Team Members

Date

Item	Issues to be Considered	Check	Comments
1 Safety aspects not already covered	Safety auditors are to check for any issue or item not already covered		
	This could include unusual events, special effects of land uses alongside, including stock being driven onto or along the road		
	The ability of the road to take overweight or over-dimension vehicles or other large vehicles <ul style="list-style-type: none"> - trucks - buses - emergency vehicles - utility/road maintenance vehicles 		
	The ability to close the road for special events in a safe manner		
	The special requirements of scenic or tourist routes		
	The provision of rest areas with safe access and egress		

Project _____
 Audit Team Members _____
 Date _____

Item	Issues to be Considered	Check	Comments
1 Changes since Stage 2	Check for any major changes in principle since the Stage 2 Audit was carried out Check that the conditions for which the project was originally designed still apply, i.e., there have not been significant changes to the surrounding network or area to be served, or traffic mix		
2 Drainage	Will the new road drain adequately? Is there a possibility of surface flooding or overflowing from surrounding or intersected drains and water courses? Is pit spacing adequate to limit flooding?		
3 Climatic conditions	Do weather records or local experience indicate a problem (e.g., snow, ice, wind, fog)?		
4 Landscaping	Check the landscape design or planting species for a lowering of safety Is it likely to lead to a lower safety with mature or seasonal growth (e.g. through loss of visibility, obscuring signs, shading or light effects, leaves, flowers or seeds dropping on to the highway)? Is frangible vegetation appropriate? Consider pedestrian visibility in particular		

Project _____
 Audit Team Members _____
 Date _____

Item	Issues to be Considered	Check	Comments
5 Services	Does the design adequately deal with buried and overhead services? Check the location of fixed objects or furniture associated with services, including for loss of visibility and check the position of lighting and other poles for accuracy Check the clearance to overhead wires		
6 Access to property and developments	Can all accesses be used safely? Are there any downstream or upstream effects from accesses, particularly near intersections?		
7 Emergency vehicles and access	Has provision been made for safe access by emergency vehicles? Check the design of medians and vehicle barriers, and the ability of emergency vehicles to stop without necessarily disrupting traffic		
8 Future widening and/or realignments	If the project is only a stage towards a wider or divided roadway, is the signing and design adequate to impart this message to drivers? Is the transition from two way to divided roadway handled safely?		
9 Staging of the project	If the project is to be staged or constructed at different times, are the construction plans and program arranged to ensure maximum safety and do they include specific safety measures, signing, also adequate transitional geometry for any temporary arrangements?		

Checklist 3-1 General Topics

Design Issues

Project _____
 Audit Team Members _____
 Date _____

Project _____
 Audit Team Members _____
 Date _____

Item	Issues to be Considered	Check	Comments
10 Staging of the works	If the construction of this project is to be staged or split into several contracts check that these are arranged for maximum safety		
11 Significant adjacent developments	Check that the design handles accesses to major adjacent generators of traffic and developments safely		
	Check the need for screening against glare from lighting of adjacent developments		
	Check that lighting or traffic signals on an adjacent road do not affect the drivers' perception of the road ahead		
12 Stability of cut and fill	Do the geological conditions in the country through which the road is to be built pose significant threats to the safety of vehicle occupants?		
	Check barriers for stability, potential for loose material		
13 Skid resistance	Check the need for high level skid surface on grades or where braking or good road adhesion is essential		
14 Maintenance	Check that maintenance vehicles can be safely located		

Item	Issues to be Considered	Check	Comments
1 Geometry of horizontal and vertical alignment	Check that the horizontal and vertical design of the project fit together comfortably Check the design for adequacy having regard to the function of the road Check the possibility of drivers not being able to read the road characteristics, i.e., visual illusions, subliminal delineation, etc		
2 Typical cross-sections	Are the lane widths, shoulders, medians and other cross section features in accordance with standard design or adequate for the function of the road?		
3 Effect of cross-sectional variation	Check that there are no variations in cross section design which could affect safety, particularly where sections of existing highway have been utilized, or there have been compromises to accommodate accesses, etc		
4 Roadway layout	Check where compromises have been made, e.g., at bridges or to avoid physical features Check that total traffic management features (i.e., in addition to questions of horizontal and vertical alignment and cross section) are not likely to create unsafe conditions. This includes the installation of signs and markings both on the road and nearby to deal with changes in alignment, particularly where these are substandard		
5 Shoulders and edge treatment	Check the safety aspects of shoulder provision, if any, including seal shoulders, the width and treatment on embankments and cross slopes of shoulders. Are the shoulders likely to be used by slow moving vehicles or cyclists?		

Checklist 3-2 Design Issues

Project _____
 Audit Team Members _____
 Date _____

Item	Issues to be Considered	Check	Comments
6	The effect of departures from standards or guidelines		
	Are there any approved departures from standards or guidelines which affect safety?		
	Are there any hitherto undetected departures from standards which should be brought to the attention of the designer?		
7	Visibility, sight distance		
	Are horizontal and vertical alignments consistent with the required visibility requirements?		
	Confirm that the standard adopted for provision of visibility in the design is appropriate for the ruling or 85th percentile speed and for any unusual traffic mix		
	Check that sight lines are not obstructed by		
	(a) Safety fences and barriers		
	(b) Boundary fences		
	(c) Street furniture		
	(d) Parking facilities		
	(e) Signs		
	(f) Landscaping		
	(g) Bridge abutments		
	Check that railway crossings, bridges and other hazards are conspicuous		
	Will sight lines be obstructed by temporary features such as parked vehicles in turn outs, or by parked or queued traffic generally?		

Checklist 3-2 Design Issues

Project _____
 Audit Team Members _____
 Date _____

Item	Issues to be Considered	Check	Comments
8	Signs and markings		
	Has the design approach taken into account the provision of signs and road markings?		
	Are they adequately detailed so as to promote good traffic management and safety?		

Checklist 3-3

Alignment Details

Project _____

Audit Team Members _____

Date _____

Item	Issues to be Considered	Check	Comments
1 Visibility, sight distance	Are horizontal and vertical alignments consistent with the required visibility requirements?		
	Confirm that the standard adopted for provision of visibility in the design is appropriate for the ruling or 85th percentile speed and for any unusual traffic mix		
	Check sight lines are not obstructed by		
	(a) Safety fences and barriers		
	(b) Boundary fences		
	(c) Street furniture		
	(d) Parking facilities		
	(e) Signs		
	(f) Landscaping		
	(g) Bridge abutments		
2 New/existing road interface	Check that railway crossings, bridges and other hazards are conspicuous		
	Will sight lines be obstructed by temporary features such as parked vehicles in turn outs, or by parked or queued traffic generally?		
	Have implications for safety at the interface been considered?		
	Include the accident rate and severity on the adjacent network, and the effect of sudden changes in the speed profile or access and side friction characteristics		
	Does the interface occur near any hazard, i.e. at a crest or bend or where poor visibility or distractions occur?		

Checklist 3-3

Alignment Details

Project _____

Audit Team Members _____

Date _____

Item	Issues to be Considered	Check	Comments
3 Readability by drivers	Check that the change is affected safely where roadway standards differ		
	Check transition is safe where road environment changes, for example, urban to rural, fast to slow, lit to unlit		
	Check the need for advance warning		
	Will the general layout, function and broad features be recognized by drivers in adequate time for safety not to be impaired?		
	If new work is of higher geometric standard - is there clear and unambiguous advance warning or reduction in standard?		
4 Detail of geometric design	Is there need for a transition zone between higher standard of new road and lower standard of old road (especially perception of horizontal curvature, which is the primary determinant out of desired speed)		
	Check the approach speed and general likely position of vehicles as they track through the project		
	Check that the design standards are appropriate for all the new requirements of the proposed project		
5 Treatment of bridges and culverts	Check for consistency of general standards and guidelines such as lane widths and cross slopes		
	Check that the geometric transition from the standard cross section to that on the bridge is handled so as to promote safety		

Checklist 3-4

Intersections

Checklist 3-4

Intersections

Project _____

Audit Team Members _____

Date _____

Item	Issues to be Considered	Check	Comments
1 Visibility to and visibility at intersection	Are horizontal and vertical alignments consistent with the required visibility requirements? Will drivers be aware of the presence of the intersection (especially if facing a Stop/Yield sign)?		
	Confirm that the standard adopted for provision of visibility in the design is appropriate for the ruling or 85th percentile speed and for any unusual traffic mix		
	Check that sight lines are not obstructed by		
	(a) Safety fences and barriers		
	(b) Boundary fences		
	(c) Street furniture		
	(d) Parking facilities		
	(e) Signs		
	(f) Landscaping		
	(g) Bridge abutments		
	Check that railway crossings, bridges and other hazards are conspicuous		
2 Layout	Will sight lines be obstructed by permanent or temporary features such as parked vehicles in turn outs, or by parked or queued traffic generally?		
	Check junctions and accesses are adequate for all vehicle movements		
	Check turning paths to establish that the layout caters for the design vehicles and other road users		
	Checks safety of any unusual features		

Project _____

Audit Team Members _____

Date _____

Item	Issues to be Considered	Check	Comments
	Check if heavy truck movements or curvature of the roadway may suggest that the opposing left turn lanes be offset to gain sight distance		
	Check need for crash attenuators or pedestrian fences		
	Check need for channelization islands and signs		
	Check features for visibility intrusion e.g. crash attenuators, pedestrian fences, signs, and traffic signals		
	Check safety where vehicles (including buses and taxis) may park or service premises within the intersection area.		
	Will the general type, function, priority rules and broad features be recognized by drivers in adequate time		
	Check the approach speed and general likely position of vehicles as they track through the project Is there anything misleading?		
	Check the layout adopted for traffic safety, compliance with standards or reason for variation, swept paths, ability to handle unusual traffic mixes or circumstances safety		
	Check that receiving lanes are 12 ft. (3.6m) wide with a 4 ft. (1.2m) outside shoulder, minimum		
	Check that roadways meet at angles of 90 degrees, and no less than 75 degrees		
	Check the correctness of the design approach speed and general likely position of vehicles		
3 Readability by drivers			
4 Detail of geometric design			

Checklist 3-4 Intersections

Checklist 3-4 Intersections

Project _____
 Audit Team Members _____
 Date _____

Project _____
 Audit Team Members _____
 Date _____

Item	Issues to be Considered	Check	Comments
5 Traffic signals	Check visibility of signal head Can drivers be confused by seeing other signal aspects within the intersection or elsewhere?		
	Check need for high intensity signals, strobes, and/or backplates if likely to be affected by sunrise/sunset		
	Check if separate signal heads are used to control movements in each lane		
	Check to see that the protected left turn phase is leading, not trailing		
	Check markings for left and right turn vehicles		
	Determine if protected-only phases can be used without an unacceptable reduction in level of service		
	Check if right-turn-on-red has been prohibited at skewed intersections if angle is less than 75 degrees or greater than 105 degrees		
	Check if street name signs are included		
	Check if overhead lane control signs are appropriate		
	Check need for pedestrian phases and/or protected turning movements		

Item	Issues to be Considered	Check	Comments
6 Roundabouts and approach islands	Check that deflection angles of approach roads are adequate		
	Check need for splitter islands		
	Check that center island is prominent		
	Check need for hazard markers and markings and that they are correctly located		
	Check need for dedicated lanes		
	Check that speeds are not likely to be greater than 50 km/h (or lower in local street)		
	Check that speeds are not likely to be greater than 50 km/h (or lower in local street)		
	Check pole location on central island and nearby curbs		

Checklist 3-4 Intersections

Project _____
 Audit Team Members _____
 Date _____

Item	Issues to be Considered	Check	Comments
7 Other intersections	Check the need for curbed or painted islands and refuges		
	Check intersection has adequate storage space for turning movements		
	Check that staggered cross roads can accommodate all vehicle types and movements		

Checklist 3-5 Special Road Users

Project _____
 Audit Team Members _____
 Date _____

Item	Issues to be Considered	Check	Comments
1 Adjacent land	Check that access to and from adjacent land/properties is safe Consider the special needs of agriculture, movements of stock		
2 Pedestrians	Check that fencing is adequate on freeways		
	Check need to deter pedestrians from crossing road at unsafe locations		
	Check if raised channelization is used in low speed areas		
	Check provision for pedestrians to cross safely at		
	(a) Intersections		
	(b) Signalized and pedestrian crossings		
	(c) Refuges		
	(d) Curb extensions		
	(e) Other locations		
	Check the following for each crossing (bridges, subways, at grade) as necessary		
	(a) Visibility		
	(b) Use by disabled		
	(c) Use by elderly		
	(d) Use by children/schools		
	(e) Need for pedestrian fencing on reservations and medians		
	(f) Signs		
	(g) Width and gradient		
	(h) Surfacing		
	(j) Avoidance of channels and gullies		

Checklist 3-5 Special Road Users

Project _____
 Audit Team Members _____
 Date _____

Item	Issues to be Considered	Check	Comments
	(k) Need for deterrent curbing		
	(l) Need for lighting		
	(m) Sited to provide maximum use		
	(n) Can their use be avoided by crossing at grade or elsewhere?		
	Check needs of cyclists have been considered		
3 Cyclists	(a) At intersections (particularly roundabouts)		
	(b) On roads having speed in excess of 50 km/h		
	(c) Bicycle routes and crossings		
4 Equestrians and stock	Check shared bikeway/footway facilities including subways and bridges are safe and adequately signed		
	Check needs have been considered and adequately signed and catered for		
5 Freight	Check needs have been considered and adequately signed and catered for		
6 Public Transport	Check that needs have been considered and adequately signed and catered for		
7 Road maintenance vehicles	Check that needs have been considered and adequately signed and catered for, i.e. crossovers, radii, sight distance concerns, etc		

Checklist 3-6 Signs and Lighting

Project _____
 Audit Team Members _____
 Date _____

Item	Issues to be Considered	Check	Comments
1 Lighting	Is this project to be lit?		
	Are there difficulties of illuminating sections of the road caused by trees or overbridges, for example?		
	Has the question of siting of lighting poles been considered as part of the general concept of the scheme?		
	Are frangible or slip-base poles to be provided?		
	Are any special needs created by ambient lighting?		
	Are there any aspects of the provision of lighting poles which would require consideration from the safety point of view in their being struck by vehicles (e.g. traffic islands)?		
2 Signs	Are sign structures needed?		
	Are signs located at points to allow adequate readability?		
	Are signs located to limit visibility from accesses and intersecting roads?		
	Are signs appropriate to the drivers needs, i.e. destination signs, advisory speed signs, etc?		
	Have the safety aspects of signs been considered as part of the general concept?		
	Are there any aspects of the provision of sign posts which would require consideration from the safety point of view in their being struck by vehicles?		
3 Marking and delineation	Check that the appropriate standard of delineation and marking has been adopted		

Checklist 3-7 Physical Objects

Project _____
 Audit Team Members _____
 Date _____

Item	Issues to be Considered	Check	Comments
1 Median barriers	Are median barriers necessary and have they been properly detailed?		
	Are there any design features such as end conditions which require special attention?		
2 Poles and other obstructions	Are there any poles located adjacent to moving traffic which could be sited elsewhere, (i.e., at the property boundary)?		
	Have frangible or breakaway poles been detailed?		
	Is the unprotected median width adequate to accommodate lighting poles?		
	Check the position of traffic signal controllers and other service apparatus		
3 Crash attenuators and guide rail	Are there any other obstructions which are likely to create a safety hazard and can they be mitigated or relocated?		
	Is a crash attenuator provided where necessary and is it properly detailed?		
	Are there any features about the design or presence of the crash attenuator which could create danger to any road user, including pedestrians?		
	Are the end conditions of the crash attenuator likely to create a safety problem?		
	Do any guide rail installations restrict sight distance?		

Checklist 3-7 Physical Objects

Project _____
 Audit Team Members _____
 Date _____

Item	Issues to be Considered	Check	Comments
4 Bridges and culverts	Is the guide rail designed according to standards - end treatments - NCHRP 350 requirements - driveway treatments - intersecting road treatments - anchorages - post spacings - block outs - post depths - rail overlaps - minimum unobstructive distances		
	Check bridge barrier and culvert end walls for		
	(a) Visibility		
	(b) Ease of recognition		
	(c) Proximity to moving traffic		
	(d) Possibility of causing injury or damage		
	(e) Collapsible or frangible ends		
	(f) The need to be able to see through bridge guard railing for safety purposes		
	(g) Signs and markings		
	(h) Connection of bridge railing to bridge posts		
	(i) Connection of approach barriers to bridge		
	(j) End post transition of stiffness between approach barrier and bridge end post		

Checklist 3-8 Construction and Operation

Project _____
 Audit Team Members _____
 Date _____

Item	Issues to be Considered	Check	Comments
1 Construct- ability	Check that traffic management provisions are adequate during construction period		
	Check that site access routes are safe		
	Check need for construction safety zones, including overhead work		
	Check need for restrictions on any road		
	Check that law enforcement and other emergency services have been consulted		
2 Operation	Check access to structures and road furniture is safe		
	Check that the road or utilities in the road reserve can be maintained safely Both road users and maintenance personnel should be considered		
3 Traffic management	Check that the traffic management of the construction site has been adequately spelled out from the safety point of view, and that the transition from the existing arrangements to the construction site and from the construction site to the final layout can be effected safely, and has been adequately detailed		
4 Network management	Check that all parking and clearway matters affecting road safety have been considered		
5 Temporary traffic control and management	Check that the arrangements for temporary traffic control or management, including possible signals, temporary diversions including signing and lighting of the site have been adequately detailed from the safety point of view		

Checklist 3-9 Other Issues

Project _____
 Audit Team Members _____
 Date _____

Item	Issues to be Considered	Check	Comments
1 Safety aspects not already covered	Safety auditors are to check for any issue or item not already covered		
	This could include		
	(a) Unusual events		
	(b) Special effects on land uses alongside		
	(c) Stock being driven onto or along the road		
	(d) The ability of the road to take overweight or over-dimension vehicles or other large vehicles - trucks - buses - emergency vehicles - utility/road maintenance vehicles		
	(e) The ability to close the road for special events in a safe manner		
	(f) The special requirements of scenic or tourist routes		
	(g) Signals not at intersections		

Checklist 4-1

Project _____
 Audit Team Members _____
 Date _____

Item	Issues to be Considered	Check	Comments
9	Staging of the project	If the project is to be staged or constructed at different times, are the construction plans and program arranged to ensure maximum safety and do they include specific safety measures, signing, also adequate transitional geometry for any temporary arrangements?	
10	Significant adjacent developments	Check effectiveness of screening of adjacent developments and other special features	
11	Batter treatment	Check that batter treatment will prevent or limit debris falling on to the roadway	
12	Shoulders and edge delineation	Check that all delineators and pavement markings are correctly in place	
13	Signs and markings	Check that all signs and pavement markings are correctly in place and that the appropriate signs have been used (i.e., Chevron Alignment Markers, etc.)	
14	Surface treatment, skid resistance	Check that they will remain visible at all times. Check that old delineation (signs, markings) have been removed, and are not liable to confuse.	
15	Contrast with markings	Check all joints in surfacing for excessive bleeding or low skid resistance.	
16	Roadside hazards	Check all trafficked areas for similar problems, including loose stones.	
		Check that the road markings as installed have sufficient contrast with the surfacing and are clear of debris.	
		Check that no roadside hazard has been installed or overlooked.	

Checklist 4-1

Project _____
 Audit Team Members _____
 Date _____

Item	Issues to be Considered	Check	Comments
1	Changes since Stage 3 and translation of design into practice	Carry out a general check - particularly for matters changed at previous audits	
2	Drainage	Check the translation of the design into its physical form and any changes that could affect safety	
3	Climatic conditions	Check drainage of road and surrounds is adequate	
4	Landscaping	Check effectiveness of any facilities put in place to counter climatic effects	
5	Services	Check that planting and species selection is appropriate from safety point of view	
6	Access to property and developments	Check for fragility, visibility and pedestrian safety in particular	
7	Emergency vehicles and access	Check that boxes, pillars, posts and lighting columns are located in safe positions	
8	Future widening and/or realignments	Are they of appropriate materials or design?	
		Check that accesses are safe for intended use	
		Check on adequacy of design and visibility in particular	
		Check that provision for emergency vehicle access and vehicles and stopping is safe	
		If the project is only a stage towards a wider or divided roadway, is the signing and design adequate to impart this message to drivers?	
		Is the transition from two way to divided roadway handled safely?	

Checklist 4-1 General Topics

Project _____
 Audit Team Members _____
 Date _____

Item	Issues to be Considered	Check	Comments
17 Natural features	Check that natural features do not create hazards or loss of visibility - trees - rocks - ditches - cut slopes - embankments - bodies of water		

Checklist 4-2 Alignment Details

Project _____
 Audit Team Members _____
 Date _____

Item	Issues to be Considered	Check	Comments
1 Visibility, sight distance	Check sight lines are not obstructed by		
2 New/existing road interface	Check the need for additional signs and/or marking		
3 Readability by drivers	Check that the form and function of the road and its traffic management are easily recognized under likely operating conditions (e.g., under heavy traffic or poor visibility conditions)		
	Check the transition between old and new alignment, that the road is "readable" and does not create uncertainty at the point of transition		
4 Treatment at bridges and culverts	Check that all markings and signs are in place and readable		

Checklist 4-3 Intersections

Project _____
 Audit Team Members _____
 Date _____

Item	Issues to be Considered	Check	Comments
1 Visibility to intersection	Are drivers aware of the presence of the intersection (especially if facing a Stop/Yield sign)?		
2 Visibility at intersection	Check that all visibility aplays or parts of the right of way required for visibility are clear for cars, trucks, and vehicles with restricted visibility (e.g., vans, cars towing trailers)		
3 Readability by drivers	Check by driving each approach that the form and function of the intersection is clear to all drivers		
	Check that the stop/yield line is clear, and that the driver is given sufficient cues to stop before protruding into conflicting traffic		
4 Traffic signals	Check alignment and general correctness of installation and that all aspects are visible from each approach lane at that appropriate distances		
	Where right-turn-on-red is permitted and a pedestrian crosswalk is delineated on the intersecting roadway, check if appropriate or if signing can be used to identify potential conflicts		
	Check that the appropriate lens size is used		
	Check markings for left and right turning vehicles		
5 Roundabouts and approach islands	Check that the roundabout or island is fully visible and recognizable from all approaches and that signs, markings, and lighting are correctly in place		

Checklist 4-4 Non-Motorized Traffic

Project _____
 Audit Team Members _____
 Date _____

Item	Issues to be Considered	Check	Comments
1 Adjacent land	Check fencing is adequate, particularly on roads where pedestrians and animals are not allowed		
2 Pedestrians	Check the following at all pedestrian facilities (a) Visibility in both directions Can pedestrians see and be seen? (b) Signs (c) Surfacing (d) Fencing (e) Operation of other hardware, including lighting (f) Are disabled pedestrians catered for?		
3 Cyclists	Check the following at all cycle ways and facilities (a) Visibility (b) Signs (c) Surfacing (d) Fencing (e) Operation of other hardware, including lighting		
4 Equestrians	Check the following at all facilities (or restrictions) (a) Visibility (b) Signs (c) Other special features		

Checklist 4-5 Signs and Lighting

Checklist 4-6 Physical Objects

Project _____
 Audit Team Members _____
 Date _____

Project _____
 Audit Team Members _____
 Date _____

Item	Issues to be Considered	Check	Comments
1 Lighting	Check operation and efficiency from safety point of view		
2 Signs, visibility and positioning	Check visibility, legend or symbol, locations and legibility both during daylight and hours of darkness		
	Check correct reflectivity or illumination		
	Check operation of variable message signs		
3 Passing zones	Check need for additional/fewer signs or for signs to be moved		
	Check that changes in roadway that reflect necessary changes to passing zones are adequately identified		
4 Marking and delineation	Ensure that delineation and markings are placed correctly and will remain fully visible		
	Ensure continuity in delineation type/standard between new and old road sections, or ensure appropriate transition		

Item	Issues to be Considered	Check	Comments
1 Median barriers	Check they are in place and properly marked, where appropriate		
	Check that they do not limit visibility or form a hazard		
2 Poles and other obstructions	Check that no poles or obstructions have been missed in other checks, and that potentially dangerous objects are properly marked, or signed or protected by crash barriers		
3 Crash attenuators and guide rail	Ensure all crash barriers are in place and do not form a hazard		
	Are there any features about the design or presence of the crash barrier which could create danger to any road user, including pedestrians?		
	Will the crash attenuators and guide rail create sight distance concerns?		
	Are the end conditions of the guide rail likely to create safety problems?		
	Is the guide rail designed according to standards		
	- end treatments - NCHRP 350 requirements - driveway treatments - intersecting road treatments - anchorages - post spacings - block outs - post depths - rail overlaps - minimum unobstructive distances		

Checklist 4-7 Construction and Operation

Checklist 4-8 Other Issues

Project _____

Audit Team Members _____

Date _____

Project _____

Audit Team Members _____

Date _____

Item	Issues to be Considered	Check	Comments
1 Operation	Check all operating features and ensure that access to them is satisfactorily installed		
2 Traffic management	Check function of all traffic management devices including readability from moving vehicles		
3 Temporary traffic control and management	Check all temporary arrangements, signing, etc have been removed and replaced by final arrangements		

Item	Issues to be Considered	Check	Comments
1 Safety aspects not already covered	Drive the site and identify any potential problems not already raised		

Checklist 5-10 Pavement

Checklist 5-1 General Topics

Project _____
 Audit Team Members _____
 Date _____

Project _____
 Audit Team Members _____
 Date _____

Item	Issues to be Considered	Check	Comments
1 Pavement defects	Is the pavement free of defects (e.g., excessive roughness or rutting, potholes, etc.) which could result in safety problems (e.g., loss of steering control)?		
2 Skid resistance	Does the pavement appear to have adequate skid resistance, particularly on curves, steep grades and approaches to intersection? Has skid resistance testing been carried out where necessary?		
3 Ponding	Is the pavement free of areas where ponding or sheet flow of water may occur with resultant safety problems?		
4 Loose screenings	Is the pavement free of loose screenings?		

Item	Issues to be Considered	Check	Comments
1 Landscaping	Is landscaping in accordance with guidelines (e.g., clearances, sight distance)? Are required clearances and sight distances not likely to be restricted following future plant growth (landscaping and natural)?		
2 Parking	Are provisions for parking satisfactory in relation to traffic operations and safety?		
3 Temporary works	Are all locations free of construction or maintenance equipment, and any signing or temporary traffic control devices that are no longer required?		
4 Headlight glare	Have any problems due to headlight glare (e.g., two-way service road close to main traffic lanes) been addressed?		

Checklist 5-2

Checklist 5-2

Project _____

Project _____

Audit Team Members _____

Audit Team Members _____

Date _____

Date _____

Item	Issues to be Considered	Check	Comments
7	Batter slopes Are the batter slopes and table drains safe for run off vehicles to traverse?		

Item	Issues to be Considered	Check	Comments
1 Visibility, sight distances	Is sight distance adequate for the speed of traffic using the route? Is adequate sight distance provided for intersections, crossings (e.g. pedestrian, cyclist, cattle, railway) etc.?		
2 Design speed	Is the horizontal and vertical alignment suitable for the (85th percentile) traffic speed? If not (a) Are warning signs installed? (b) Are advisory speed signs installed? Are the posted advisory speeds for curves appropriate?		
3 Overtaking	Are adequate overtaking opportunities provided?		
4 Readability by drivers	Are there any sections of roadway which may cause confusion e.g. (a) Is alignment of roadway clearly defined? (b) Has disused pavement (if any) been removed or treated? (c) Have old pavement markings been removed properly? (d) Do streetlight and tree lines conform with the road alignment?		
5 Widths	Are all traffic lanes and roadway widths, including bridges, adequate?		
6 Shoulders	Are shoulder widths appropriate (e.g. for broken down or emergency vehicles)? Are shoulders traversable for all vehicles and road users? Is the shoulder cross slope sufficient to provide proper drainage?		

Checklist 5-4 Auxiliary Lanes and Turn Lanes

Project _____
Audit Team Members _____
Date _____

Item	Issues to be Considered	Check	Comments
1 Tapers	Are starting and finishing tapers located and aligned correctly?		
2 Shoulders	Are appropriate shoulder widths provided at merges in accordance with design guidelines?		
3 Signs	Is signing and marking installed in accordance with standards?		
4 Turning traffic	Is there advance warning of the approaching auxiliary lane?		
5 Visibility, sight distances	Have right turn movements within the length of the auxiliary lane been avoided?		
	Has stopping sight distance been provided to the rear of turning vehicles?		
	Has stopping sight distance been provided for entering and leaving vehicles?		

Checklist 5-3 Intersections

Project _____
Audit Team Members _____
Date _____

Item	Issues to be Considered	Check	Comments
1 Location	Are intersections located safely with respect to horizontal and vertical alignment?		
2 Warning	Where intersections occur at the end of high speed environments (e.g., at approaches to towns), are there traffic control devices to alert drivers?		
3 Controls	Are pavement markings and intersection control signing satisfactory?		
4 Layout	Is the alignment of curbs, traffic islands and medians satisfactory?		
	Is the intersection layout obvious to all users?		
	Are turning radii and tapers appropriate?		
5 Visibility, sight distances	Is sight distance adequate for all movements and all users?		

Safety Audit Stage 5 **Operation/Existing Roads**

Checklist 5-5 **Non-Motorized Traffic**

Project _____
 Audit Team Members _____
 Date _____

Item	Issues to be Considered	Check	Comments
1 Paths	Are there appropriate travel paths and crossing points for pedestrians and cyclists?		
2 Barriers and fencing	Where necessary, is fencing installed to guide pedestrians and cyclists to crossings or overpasses? Is fencing of your design (e.g., avoid solid horizontal rails)? Where necessary, is crash barrier installed to separate vehicle, pedestrian and cyclist flows?		
3 Bus stops	Are bus stops appropriately located with adequate clearance from the traffic lane for safety and visibility?		
4 Elderly and disabled	Are there adequate provisions for the elderly, the disabled, children, wheelchairs and baby carriages (e.g., holding rails, curb and median crossings, ramps)? Where necessary, are hand rails provided (e.g., on bridges, ramps), and are they adequate?		
	Distance between stop line and pedestrian crossing at signalized intersections (for visibility of pedestrians from truck driver's seat)		
	Signal timing - cycle length - pedestrian clearance time - are pedestrian buttons operable?		
5 Cyclists	Is the pavement width adequate for the number of cyclists using the route? Is the bicycle route continuous, i.e., free of squeeze points or gaps? Are bicycle safe grades provided at drainage pits where necessary?		

Safety Audit Stage 5 **Operation/Existing Roads**

Checklist 5-6 **Signs and Lighting**

Project _____
 Audit Team Members _____
 Date _____

Item	Issues to be Considered	Check	Comments
1 Lighting	Is appropriate lighting installed at intersections, roundabouts, pedestrian and bicycle crossings, pedestrian refuges, etc? Is all lighting operating satisfactorily? Are the appropriate types of poles used for all locations and correctly installed (e.g. slip base at correct height, rigid poles protected if within clear zone)? Are all locations free of any lighting which may conflict visually with traffic signals or signs?		
2 Signs	Has lighting for signs, particularly overhead signs, been provided where necessary? Are all necessary regulatory, warning and direction signs (including detours) in place? Are they conspicuous? Are there any redundant signs? Are traffic signs in their correct locations, and properly positioned with respect to lateral clearance and height? Are the correct signs used for each situation, and is each sign necessary? Are signs placed so as not to restrict sight distance, particularly for vehicles? Are all signs effective for all likely conditions (e.g. day, night, rain, fog, rising or setting sun, oncoming headlights, poor lighting)? Do sign supports conform to guidelines?		

Checklist 5-6

Signs and Lighting

Item

Issues to be Considered

Check

Comments

3

Marking and delineation

Have retroreflective markers been installed? Where colored markers are used, have they been installed correctly?

Is all necessary pavement marking installed?

Are pavement markings (center lines, edge lines, transverse lines) clearly visible and effective for all likely conditions (e.g. day, night, rain, fog, rising or setting sun, oncoming headlights, light colored pavement surface, poor lighting)?

On light coloured pavement surfaces (e.g. concrete) are RRPMS used to simulate traffic lanes?

Has raised profile edge marking been provided where necessary (e.g. fatigue zones)?

Is delineation adequate and in accordance with guidelines (e.g. post-mounted delineation, RRPMS, chevron alignment markers)?

Is delineation effective for all likely conditions (e.g. day, night, rain, fog, rising or setting sun, oncoming headlights)?

If chevron alignment markers are installed, have the correct types of markers been used?

Are vehicle paths through intersections delineated where required?

On truck routes, are reflective devices appropriate to driver's eye height?

Checklist 5-8

Physical Objects

Checklist 5-9

Delineation

Project _____

Audit Team Members _____

Date _____

Project _____

Audit Team Members _____

Date _____

Item	Issues to be Considered	Check	Comments
1 Clear zone	Is a clear zone provided in accordance with the guidelines? Is the appropriate treatment or protection provided for any objects within the clear zone (e.g., slip-base or frangible poles, crash barrier, crash cushions, sloping culvert, headwalls)?		
2 Crash barriers	Are safety barriers installed at all necessary locations, including on bridges, in accordance with guidelines? Are the crash barrier systems suitable for the purpose? Is the length of crash barrier at each installation adequate? Are the crash barriers correctly installed? Are Guard Rail Energy Absorbing Terminals (GREAT) or crash cushions installed where necessary (e.g., off ramp, bridge piers)? Where works are subject to stage construction, are temporary barriers installed in accordance to guidelines? Is there a safe run off area behind breakaway terminals?		
3 Fencing	Is pedestrian fencing where needed? Is fencing in the clear zone free of separate horizontal rails? Is there adequate delineation/visibility of barriers and fences at night?		

Item	Issues to be Considered	Check	Comments
1 Linemarking	Are all linemarkings (center line, edge line, transverse lines) in good order?		
2 Guide posts	Are guide posts correctly placed, clean, and visible?		
3 RRPMs	Are RRPM's in good order?		
4 Chevron Alignment Markers	Are Chevron Alignment Markers placed correctly and used only according to standards?		

Road Safety Audits in Canada Early Success Stories

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SUMMARY

Road Safety Audits (RSA) have been employed mostly on major projects in Canada since first employed in early 1997. RSAs are being accepted across the country with minor changes to reflect legal and instructional concerns.

For RSA to go beyond checklists for experts will require the introduction of risk. In this paper the authors outline a procedure to develop an analytical risk equation. The risk equation will allow highway designers to consider the human factors of driving, reliability of engineering design and the consequences of failure.

INTRODUCTION

Road safety audits and reviews have been a formalized analysis process for more than two decades. These formal safety-focused analyses started during the early 1980's in the U.K. (see, B. Sabey (1993), S. Proctor and M. Belcher (1993)), moved to Australia in the early 1990's (P. Jordan and E. Barton (1992)) and New Zealand (Chadfield (1998)), then on to many other countries. The process has been modified to reflect local requirements and has generally been thought to yield substantial benefits.

The introduction to North America started in the mid 1990's. The first formal audit in North America, following the Australian model, was in early 1997 of the Highway 1 HOV design in Vancouver, Canada, by Professor Navin and Hamilton Associates. The U.S. Federal Highway Administration has had extensive trials running in Pennsylvania since 1997, after a study tour to Australia. The details of road safety audits in North America, like their prototypes in Australia and the UK, reflect the instructional needs of the local areas.

FORCES FOR ROAD SAFETY AUDITS

Road safety audits emerged in the U.K. as a local county council initiative as a result of poor highway design. The U.K. Department of Transportation required preliminary, detailed, and pre-opening safety audits starting in 1991.

The need for safety audits in North America comes about for a number of reasons. The first and most powerful is a successful prototype in Australia, New Zealand and the U.K. Canadian highway designs are frequently subjected to Value Engineering (VE) reviews. The Highway 407 Safety Review (1998) reported that VE is often a cost cutting exercise. The basic assumption of VE is that if existing standards are met, safety is satisfied. Most knowledgeable engineers recognize that compliance with highway design standards does not insure safety.

There is also an economic and social need to improve road safety. The cost of insurance continues to rise as the number of collisions and injuries rise almost in lock step with increased automobile travel. The total cost of collisions represents about one percent of the GNP of most nations.

The current situation requires road safety audits to ensure that safety is adequately considered. This then implies that we either do not know enough about road safety to adequately represent it in the design standards, or that it has a very small role to play when compared to the operational and construction costs.

CANADIAN EXPERIENCE

The Canadian road safety audit experience commenced in British Columbia and started in 1995/1996, when the Insurance Corporation of British Columbia (ICBC) commissioned fact-finding studies to review the concept and the lessons learned in other jurisdictions. Most of the audit experience has been supported by ICBC.

First Audit and Lessons Learned

The first road safety audit in British Columbia was conducted early in 1997, and this is believed to be the first formal audit undertaken in North America. The Ministry of Transportation and Highways and ICBC commissioned an audit at the 50% design stage of the Highway 1 HOV lanes project in suburban Vancouver. The audit process proceeded smoothly, and the Ministry responded to the audit recommendations as required by the formal audit process. The lessons learned from this first experience included.

- the need for the audit team to provide a set of recommendations for consideration to address the safety issues that are raised by the audit,
- the need for the audit to acknowledge that some design decisions are dictated by policies and standards that are beyond the control of the design team, and therefore the audit recommendations should address policy decisions when appropriate.

The majority of British Columbia's road safety audits have been for major highway, bridge, and interchange projects, with capital costs of up to \$100 million. Several audits have also been conducted for smaller intersection upgrade projects. The audits undertaken to date are listed in Table 1.

Other Experience in Canada

Ontario

The pre-opening safety review of Highway 407, north of Toronto, was undertaken early in 1997. While not formally an audit, this safety review received national media attention and helped designers and transportation engineers focus on the importance of explicitly accounting for road safety at the design stage.

Table 1 – Typical Audit Recommendations

PROJECT DESCRIPTION & AUDIT TYPE	LOCATION	Improve Clear Zone / Traversability	Improve Sight Distances	Provide Median Barriers / End Treatments	Improve Lighting	Improve Weaving / Left Merges / I/C Spacing	Protect Structure / Hazards	Improve Drainage	Improve Pedestrian / Bicycle Facilities	Improve Cross Section, Lane Width, Shoulder, Superelev'n, Curb	Better Provisions for Buses / Trucks	Improve Signing	Improve Interchange Ramps (radii, grades)	Improve Vertical Alignment	Improve Horizontal Alignment / Turn Radii	Improve Design Consistency / Human Factors	Improve Traffic Control / Warning Devices
Highway 407, Pre-Opening	ON	●					●				●	●	●				
Highway 1 HOV Lanes, 50% Design	BC	●	●	●	●	●	●	●				●					
Fredencton - Moncton Highway, Preliminary Design	NB	●	●	●		●		●		●		●	●	●	●	●	
Vancouver - Richmond Rapid Bus, Preliminary Design	BC					●			●	●	●	●					
Highway 401 Widening, Preliminary Design	ON		●	●						●			●	●			
Highway 1 / 200 Street I/C, Detailed Design	BC										●		●				●
Dogwood at Belaire & Bayview, Conceptual Design	BC						●	●	●	●					●		
River Road at Nordel Way, Preliminary Design	BC				●				●		●						●
Lions Gate Bridge Upgrade, Preliminary Design	BC								●	●							
67 Street / 30 Avenue, Preliminary Design	AB		●	●				●	●	●	●						●
Highway 407 Extension, Preliminary Design	ON		●										●	●	●	●	
Glenrosa Interchange, Preliminary Design	BC					●		●	●								
TOTAL		3	5	4	2	4	3	5	6	6	5	4	5	3	3	2	3
TOP RANKED ISUSES			#2	#3		#3		#2	#1	#1	#2	#3	#2				

The Ministry of Transportation of Ontario has adopted refined procedures to maintain the focus on road safety throughout the planning / design / policy setting cycle. Road safety "assessments", as audits are called in Ontario, are part of the refined procedures.

Road safety reviews and audits have been undertaken for several projects in Ontario since 1998, including the extension project for Highway 407 as part of a Design/Build proposal; a section of Highway 12 as part of the preliminary design; and a section of Highway 401 as part of a widening project. Similar to British Columbia, audits are being applied generally to larger scope projects with multi-million dollar capital costs.

Alberta

Road safety audits were introduced to Alberta in 1998, and the first formal audit was undertaken for the widening of 67 Street and 30 Avenue in the City of Red Deer. In 1999, a road safety audit was prepared for an existing interchange in the City of Edmonton. The City of Calgary is currently considering the application of road safety audits for major interchange projects.

New Brunswick

The new Fredericton-Moncton Highway has provided an opportunity for audits to be introduced to New Brunswick. In 1997 a safety audit was prepared for this major Design/Build facility as part of the proposal preparation stage, and road safety audits are being conducted during the detailed design stage. The University of New Brunswick is researching audits from the perspective of Atlantic Canadian conditions.

Experience on Design/Build Projects

In addition to the above, the value of road safety audits on Design/Build projects has been recognized, and this is an area where the Canadian experience is at the forefront of audit applications. Several major Design/Build projects commissioned by the British Columbia Ministry of Transportation and Highways since 1998 have had a requirement for a road safety audit. The Design/Build proponent teams, typically consisting of a partnership between contractors and engineers, are required to retain an independent road safety audit team to formally review the design at designated stages (typically at the preliminary and detailed stages), and to prepare audit reports that the design team then responds to. Given the time and budget pressures typically imposed on Design/Build projects, safety audits are now seen as a critical component. The Design/Build projects range in value from \$2 million to \$30 million. Alberta and Ontario are other provinces that are introducing safety audit requirements into Design/Build projects.

Most Common Audit Recommendations

Based on the Canadian road safety audit experience, the most common safety audit recommendations as derived from selected projects have been summarized and compiled as shown in Table 1

Table 1 indicates that the two issues most commonly addressed in audit recommendations are cross-sectional design elements and pedestrian/bicycle facilities. This finding indicates that while designers typically address vertical and horizontal alignment issues with a high level of in-built safety, issues related to lane width, shoulder width and super-elevation are more prone to safety concerns. As well, issues related to crosswalks, sidewalks, cyclist paths, and non auto network continuity are commonly introducing safety concerns as identified by audits. This finding is probably to be expected since accommodating pedestrians and cyclists is a relatively new phenomenon compared to traditional design practices on major highway facility projects.

It is noted that Table 1 simply summarizes the audit recommendations under broad headings. The recommendations may or may not have been adopted by the design team.

Road Safety Audit, Beyond Checklists

The key objective of Road Safety audits is to reduce the inherent risk of travel prior to the public opening of the road. The lack of road safety or danger may be defined as the risk of travel. The risk equation is simply:

$\text{Risk} = \text{Exposure} * \text{Probability of the event} * \text{Consequence of the event}$

A risk approach to road safety audit has been proposed by Waught (1998) and Chadfield (1998). Chadfield (1998) quotes from Transfund New Zealand Safety Audit Procedures to explain the ranking of recommendations based on risk, as given in the "outcome table" of Table 2. The probability measure is the total collisions per year. This combines exposure and the probability of a crash. The procedure allows recommendations to be ranked by their urgency.

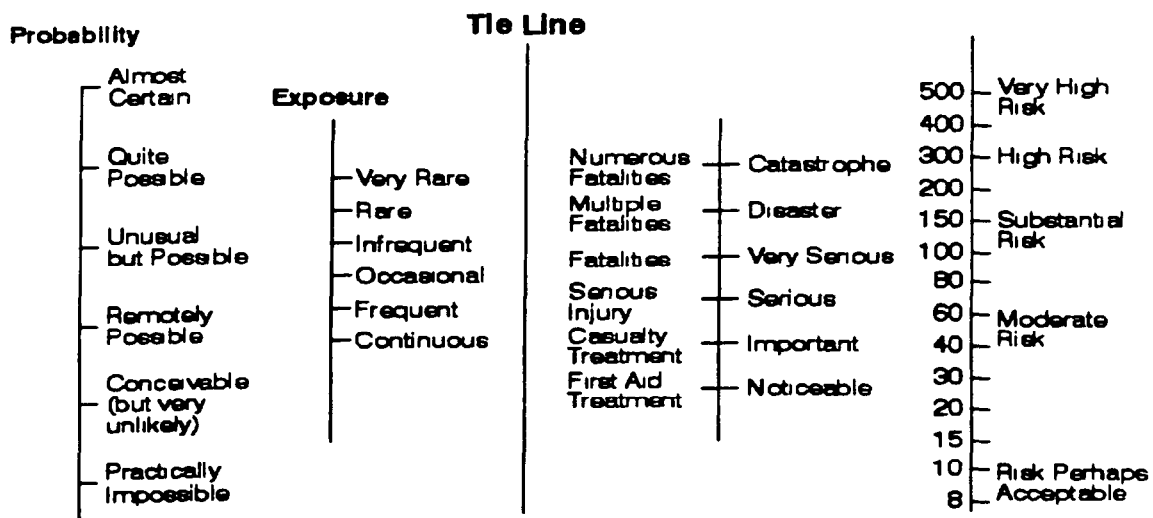
Table 2 - Risk Level for Road Safety Issues

Severity of Crash	Probability		
	Frequent one+/year	Occasional once/1-5 years	Improbable
Fatal	Urgent	High risk	Medium risk
Serious	High risk	Medium risk	-
Minor	Medium risk	-	Low risk

The road safety audit procedures of Western Australia include a nomograph solution to the risk equation to develop a risk rating. The nomograph is shown in Figure 1. Figure 1 is more useful to the safety analysts than Table 2 since it explicitly allows exposure to be factored into the risk rating.

Both these approaches show that road safety audits should go beyond the current preoccupation with checklists for experts. The ability to go beyond simply identifying problems assumes a more precise understanding and/or an ability to study from a sound theoretical base of understanding.

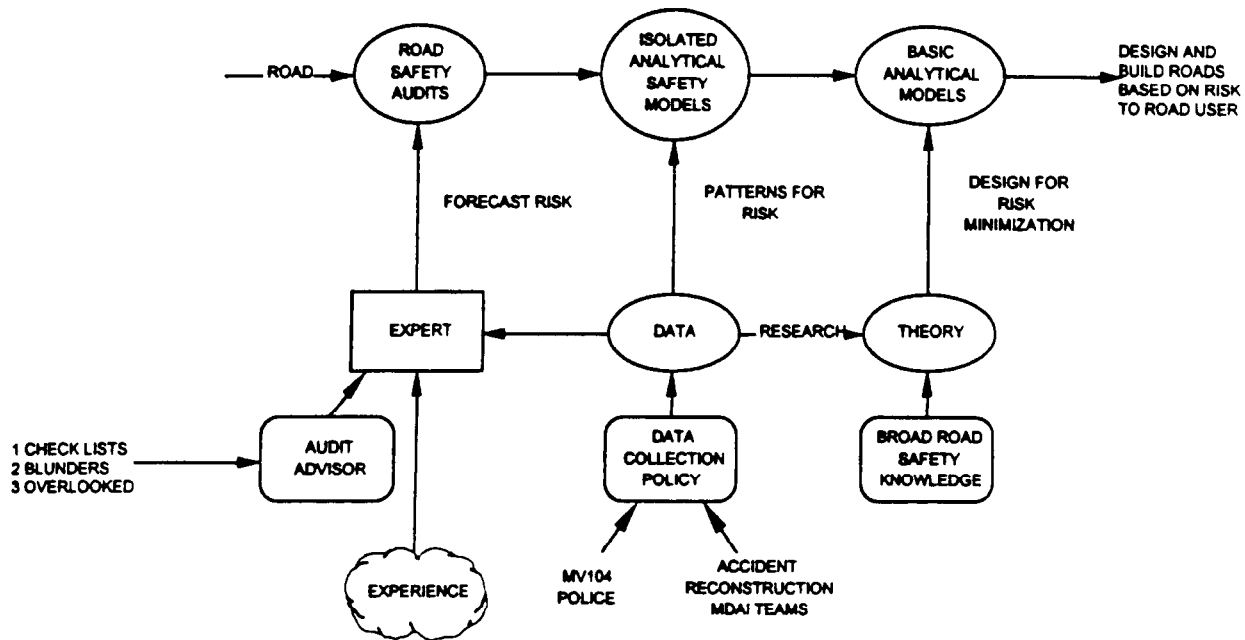
Figure 1 – Risk Score Calculator
Source: National Safety Council of Australia Ltd.



The Expert and Beyond

The ideal safety auditor has the characteristics of a team of people. The safety auditor should have experience at road design and operations, be competent in accident reconstruction, and also understand the travelling needs and habits of all road users. Expertise requires considerable time to develop and an adequate scope to practice. In any given area of endeavor, there are only a limited number of experts.

Figure 2 is a simplified diagram of the critical elements that go into a road safety audit. A new design or existing road needs to be audited by an expert. The role of the expert is to forecast risk and to make recommendations to reduce risk.

Figure 2 - Road Safety Audits, A Scheme to go Forward

The next step needed to extend the usefulness of road safety audits is to develop isolated analytical safety models. This work is and has been actively pursued by the research community for the last twenty years or more. The role of this research is to identify patterns of reported or observed risk so they may be forecasted at similar locations. Researchers such as Hauer et al (1988), and Sayed et al (1998) have developed extensive and elaborate regression models of varying levels of detail to forecast collisions. These models are aggregate unit risk models that forecast the combined results of the probability of a collision and the consequences. A deficiency of the models is that they do not permit the road designer to trade off the probability of a crash and the consequences of a crash. The success of regression models is determined in part by the quality of the accident data. The data is usually obtained from the police accident form, or specialized accident reconstruction teams.

The final step in the development of road safety audits is to derive Road Safety Analytical Models from first principles. This work was started by researchers such as Solomon (1964) and Nilsson (1993) and is being further developed by Navin (1999) and others. The key ingredients in this research are a broad road safety knowledge, adequate mathematical skill and access to detailed and accurate data. The role of this work is to develop models that help the engineer to design roads that minimize the traveler's risk. These analytical road safety models should reduce the need for road safety audits.

Proactive Road Safety Design

The purpose of proactive road safety design or safety conscious design is to explicitly estimate risk. Not only should the total risk be estimated but also the components of risk. The following discussion will outline models for the driver, the road, the vehicle and consequences.

Drivers are given road guidance advice by a set of traffic signs that are sequenced using Positive Guidance. The positive guidance principle is: if it is impossible to build what drivers expect then it is necessary to tell the driver what to expect. This simply says you should have "self explaining" roads but, if for some reason you cannot, then you may use Bayes' Rule to estimate driver expectations. Bayes' Rule for a driver may be formulated as:

$$P(B_{GR}|A) = \frac{P(A|B_{GR}) P(B_{GR})}{P(A)}$$

where, $P(B_{GR}|A)$ = The probability that a driver expects a good road ahead given warning advice A
 $P(A|B_{GR})$ = The driver's probability that warning A will be present on a good road (GR)
 $P(B_{GR})$ = The driver's prior (expectation) probability that the road is a good road (GR)
 $P(A)$ = The total probability of the warning sign by road type

This equation simply states a driver's belief that a road is "good" in spite of a warning sign A. This relationship may be thought of as the "truth in signing" rule. For example, if the driver does not believe that you, as the design engineer, would place a dangerous curve on a good highway, even though you put up a warning sign A, you are not believed so $P(A|B_{GR})$ will be small and you will have little influence on the driver.

An analytical approach such as this needs to be developed for traffic signs so engineers may estimate a sign's influence before it is installed. The current system of manuals requires no calculation and this in turn does not permit analysis and gives no estimate of a sign's effectiveness. The sign control manuals assume drivers have perfect understanding of an obscure coding system that is only fully appreciated by a few human factors experts.

Road safety developed during design may be studied by reliability analysis. This approach has been successfully applied to engineering. The design engineer need only define a failure mechanism such as stopping sight distance. The expected demand function for stopping sight distance can then be developed for specific conditions. The supply function of the engineering characteristic comes from design standards or analytical models. Given the demand and supply function, there then exists a general performance function, G such that.

$$G = g(S-D) > 0$$

where, G = a general function of performance,
 S = the supply function of an engineering measure, and
 D = the demand function of an engineering measure.

If the demand is greater than supply of the engineering measure, the system does not comply with design standards and, by definition, has failed. There are a few safety related measures derived from the general equations, specifically,

$$\text{Margin of Safety} = E(S) - E(D)$$

$$\text{Reliability Index} = \beta = \frac{E(S) - E(D)}{[\text{Var}(S) + \text{Var}(D)]^{\frac{1}{2}}}$$

where, $E(S)$ = the expected value of the supply characteristic
 $E(D)$ = the expected value of the demand characteristic
 $\text{Var}(S)$ = the variance of the supply characteristic
 $\text{Var}(D)$ = the variance of the demand characteristic

Given the reliability index, then the probability that $D > S$ may be estimated as a 1:x chance of occurrence, or the $P(D > S)$. For example, a truck breaking for an emergency (locked wheels) has a 1:10 chance of exceeding the minimum AASHTO stopping sight distance on a wet pavement (see Navin (1992))

The $P(D > S)$ is a necessary but not sufficient condition for a collision. The total probability of a crash may be estimated as:

$$P(\text{crash}) = P(\text{crash} | D_{EM}) P(D_{EM} > S_{EM})$$

where, $P(\text{crash})$ = probability of a crash

$P(\text{crash} | D_{EM})$ = probability of a crash given some design measure, D_{EM}

$P(D_{EM} > S_{EM})$ = probability that demanded engineering measure D_{EM} , exceeds supply S_{EM} .

These relationships may be replaced by equations derived either from observations, first principles or both.

The simplest relationship between a vehicle, road and driver is the friction circle or friction ellipse. The relationship simply illustrates the best possible traction between the vehicle's tires and the pavement for acceleration, turning and braking or combinations. These characteristics are usually incorporated in the mathematical relationships presented for the reliability of the engineering element of the road.

The consequences of a crash have been well documented by Ashton (1982), Nilsson (1993) and others. In equation form the results are:

$$c = aV_c^n$$

where, c = consequences

V_c = speed change during collision

a = calibration constant

n = exponent, 4 for fatalities, 3 serious injury, 2 for PDO

Final Risk Equation

All the previous results may be combined to give a risk equation that will permit detailed engineering analysis. The equation is:

$$R = E[P(B_{GR} | A) P(\text{crash} | D_{EM}) P(D_{EM} > S_{EM})] aV_c^n$$

The relationship that will eventually evolve will be complex. It will require considerable research and testing to become operational. Once the equation is made operational then the road designer will complete many of the road safety auditor's tasks. The auditor will take on a more difficult level review of road safety issues possibly within the value engineering process as well as the pre-opening audits.

CONCLUSION

The long run improvements require a theoretical approach that is based on risk minimization. To do this requires a more fundamental understanding of the mechanics underlying the risk equation. There are suggested analytical approaches combining Bayes' Rule to estimate driver expectations, reliability analysis to study the demand and supply of engineering measures, and equations to

estimate consequences. One of the more difficult areas of research will be that of dealing with the driver. Currently, human factors is an ill-defined discipline populated by a few experts who are unable to make the area analytical in a mathematical sense.

There will be increased mathematical complexity to use this new approach. The increased complexity is needed to allow designers to estimate the risk associated with their design. The ability to estimate risk and understand the mechanics behind risk, will allow highway design engineers to respond with more authority to challenges based only on "common sense". Ultimately such theory will be a practical tool to help achieve a safer road in design.

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ROAD SAFETY IN EUROPE, SEPTEMBER 21-23 1998

DESIGNING WITH SAFETY IN MIND

By Steve Proctor and Martin Belcher, Directors, TMS Consultancy
and Steve Lawson and Bert Morns, Automobile Association

1. ABSTRACT SUMMARY

The work described in this paper was commissioned by the Automobile Association (AA) to promote action arising from some of the AA Foundation for Road Safety Research studies. As part of the work, the AA and TMS Consultancy gathered together a panel of experienced Road Safety Auditors and asked them to provide a list of their "top 20" commonly identified Safety Audit problems.

There was surprisingly close agreement between the auditors, with many problems being identified on a number of occasions.

The output from the exercise will be a booklet, due to be published later this year.

2. BACKGROUND

Trunk road and motorway schemes are designed to guidance set out in a series of Advice Notes and Standards produced by the Highways Agency, The Scottish Office, the Welsh Office and the Department of the Environment in Northern Ireland. One of the principal objectives of the guidance is to ensure that new and improved roads operate safely. Highway Authorities for other road schemes (local authorities) generally design major roads to the same principles but will often have their own design guides for residential and industrial estate roads.

Road Safety Audits are carried out to minimise accident occurrence once schemes have opened. The Road Safety Audit process has been compulsory on trunk road and motorway schemes since 1991^(1,2), and most local authorities now use a similar process on schemes on local roads⁽³⁾. Road Safety Audit involves checking schemes at a number of formal stages during the design process.

Despite the use of current design standards, accidents do occur on some schemes when completed. On local roads it is not always possible to keep to design guidance, whilst at the same time constructing schemes within highway land and within budget.

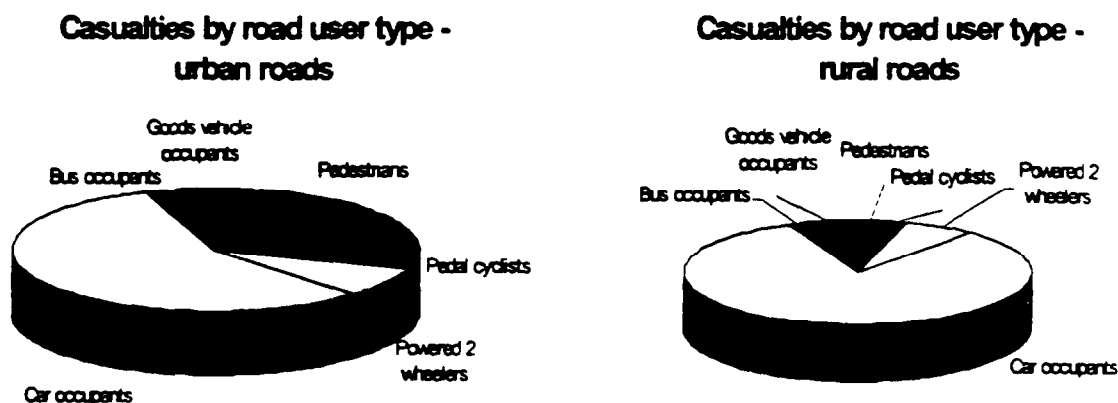
One of the benefits of Road Safety Audit is that the auditor can suggest measures that mitigate against the constraints imposed upon the design. In addition, the Road Safety Audit process is intended to identify potential accident problems that arise through a combination of design elements. For example, where a steep downward descent, a bend, and a change in carriageway type occur at the same point. Road Safety Auditors are also expected to identify design errors that could lead to accidents and to use their experience to suggest road safety engineering treatments within the design process.

3. ROAD ACCIDENTS INVOLVING DIFFERENT ROAD USERS

The Road Safety Auditor uses road safety experience to identify those aspects of schemes that are likely to cause injury accidents. Knowledge of how accidents are caused, national and local accident trends, and the effectiveness of accident remedial treatments are essential qualities of Road Safety Audit experience. This

section of the paper provides a background to the scale of accident problems for various road users

In 1996, a total of 320,302 people were reported killed or injured in 235,939 road traffic accidents in Great Britain⁽⁴⁾. The charts show the difference in the road user casualty profile between urban and rural roads



3.1 Pedestrians

In 1996, a total of 46,381 pedestrians were killed or injured in road accidents - 15% of all accident casualties. Forty per cent of these were children under the age of 16. Most pedestrians - 95% of the total - were injured on built-up roads. When accident risk is measured in terms of accidents per distance travelled, pedestrians are shown to be extremely vulnerable.

3.2 People with disabilities

The Office of Population Censuses and Surveys has estimated that 14% of the British adult population has some form of physical, sensory or mental handicap⁽⁵⁾. Around 10% of the adult population have some form of mobility handicap. People with disabilities can sometimes be drivers or cyclists, but most often they will be pedestrians, some of whom will be in wheelchairs. Information on disability is not routinely recorded in police accident records and it is therefore difficult to estimate the scale of this problem. However, a Transport Research Laboratory report produced in 1995 revealed that 29% of people with a visual impairment reported that they had been involved in an accident whilst crossing a road⁽⁶⁾.

3.3 Cyclists

In 1996, a total of 24,534 pedal cyclists were killed or injured in road accidents - 8% of all accident casualties. One third of these were a child under the age of 16. Most pedal cyclists - 91% of the total - were injured on built-up roads. Studies have shown that cycle casualties are more likely to be under-reported than injuries involving other road users. Cyclists are particularly vulnerable at roundabout junctions. Like pedestrians, cyclist casualties are high in terms of accidents per distance travelled.

3.4 Motor cyclists

In 1996, a total of 23,044 motor cyclists and pillion passengers were killed or injured in road accidents - 7% of all accident casualties. This figure includes moped and motor scooter riders and passengers. Three quarters of the casualties were injured on built-up roads.

3.5 Vehicle users

Other vehicle users comprise car drivers and passengers, bus occupants, and goods vehicle drivers and passengers. In 1996, 205,277 car occupants, 8,531 bus occupants, and 10,458 goods vehicle occupants were killed or injured in road accidents.

In 1996, just over 60% of all reported injury accidents in Great Britain took place at junctions. Just over 12% of these junction accidents were at roundabouts.

3.6 Location specific "control data"

Safety Auditors are expected to have a thorough knowledge of the type of problems likely to be associated with schemes, and the type of solutions that will prevent accidents from occurring. Ideally it should be possible to accurately predict the accident frequency likely to occur with any proposed highway scheme. However the random distribution of accidents makes predicting numbers extremely difficult. No two schemes are identical in terms of land use, engineering detail, traffic flow and mix, and this makes it difficult to use an accident frequency at an existing scheme as a predictor for a new scheme.

It is possible to use control data to generate information on the type of accidents likely to be associated with certain elements of design. Roundabouts have been shown to be very poor in terms of accidents involving two-wheeled vehicles, traffic signals have a high proportion of right turning accidents, and loss of control accidents occur on the outside of high speed bends.

Safety Auditors should also use information from before and after studies help determine which solutions will be most appropriate to the problems that they have identified. For example, anti-skid road surface treatments have been shown to reduce accidents by just over 50%.

4. THE MOST COMMONLY IDENTIFIED DESIGN PROBLEMS

In order to highlight some of the problems most commonly identified within Road Safety Audit, the AA and TMS Consultancy brought together a group of seven experienced Road Safety Auditors. The Auditors represented both the private and public sector, and were drawn from organisations in England, Scotland and Wales. Between them, they had experience of several thousand Safety Audits, on a wide range of urban and rural schemes. The Auditors were tasked to identify a range of typical Road Safety Audit issues relating to different road users.

TMS Consultancy, based on their experience of carrying out over 500 Safety Audits, initially produced a list of 52 common problems. This list was discussed with the wider group of Auditors, and each member of the group then independently identified their own "top 20" problems from the original list. The individual lists were drawn together to form the composite "common problems" list shown in Table 1.

Table 1: List of common Road Safety Audit problems

Road User	Location	Problem	Score
Vehicle user/cyclist	Roundabout	lack of deflection encouraging high entry speeds	6
Vehicle user	Link	actual speeds greater than design speed	5
Cyclist	Link	lack of continuity	4
Pedestrian	All	poorly sited crossings / routes not on desire lines	4
Vehicle user	Link	signs/lamp columns in front of safety fence/signs unprotected	4
Vehicle user	Link/junction	signs obscured by vegetation (or other obstructions)	4
Visually impaired	All	poorly designed tactile paving / tactile paving omitted	4
Pedestrian/ wheelchair user	All	lack of dropped crossings / crossings not flush	4
Cyclist	Link	missed opportunity for cycle lanes	3
Cyclist	Link	poorly sited street furniture obstructing cycleways	3
Motor cyclist	Roundabout	Inspection chamber covers in circulatory section and exits	3
Pedestrian/ wheelchair user	All	poorly sited street furniture obstructing footways	3
Pedestrian	All	lack of guard rails / not high visibility	3
Vehicle user	Link	embankments unprotected	3
Vehicle user	Roundabout	too many entry lanes	3
Cyclist	Link	lack of direction/warning/regulatory signs	2
Cyclist	Pelican crossings	missed opportunity for toucan	2
Vehicle user	Link	see-through on existing roads	2
Vehicle user	Link	poorly sited laybys	2
Vehicle user	Link	lack of temporary signs	2
Vehicle user	Roundabout	poorly sited street furniture (especially chevron signs / mini roundabout signs)	2
Vehicle user	Roundabout/ traffic signals	lack of anti-skid or insufficient length	2
Vehicle user	Traffic signals	poorly sited signal heads/ signal heads obscured	2

(The score indicates the degree of consensus between the seven Safety Auditors on each of the issues)

The most common problem identified relates to roundabout design and the lack of entry deflection, which leads to high entry speeds and possible loss of control

accidents, or entry/circulating accidents. Pedal cyclists and motorcyclists are particularly vulnerable at roundabouts and are over-represented in the accident statistics.

Other common design problems include a lack of continuity in provision for cyclists, poorly sited pedestrian crossings, and inadequate or inappropriate design of features for road users with mobility handicaps.

5. SAFETY AUDIT PROBLEMS FROM A ROAD USER PERSPECTIVE

Road Safety Audit involves a number of detailed checking processes. In addition to the interaction between design elements, one of the other important checks carried out involves assessing the safety of the scheme from different potential road users' perspectives. During the design stages the Auditor has to imagine what it would be like to walk, cycle and drive the scheme. The Auditor tries to develop scenarios when reading the scheme plans - "what happens if a bus pulls out from this lay-by at the same time as a motor-cyclist travels around this bend?"

The problems listed above were summarised from a road user perspective, to illustrate the specific safety problems identified for each user group.

Pedestrians

- poorly sited crossings / routes not on desire lines
- lack of guard-rail / guard-rail not "high-visibility"

People with disabilities

- lack of tactile paving / poorly designed tactile paving
- lack of dropped crossings / crossings not flush

Cyclists

- lack of continuity of cycle facilities
- missed opportunity for facilities
- lack of signs

Motor cyclists

- chamber covers in circulatory carriageway and exits at roundabouts

Vehicle users

- ◆ on links
 - actual speeds greater than design speed
 - signs obscured by vegetation or other obstructions
 - street furniture unprotected or in front of safety fence
 - embankments unprotected
- ◆ at junctions
 - lack of entry path deflection at roundabouts
 - lack of anti-skid surfacing at junctions and pedestrian crossings
 - poorly sited traffic signal heads / signal heads obscured

6. EXA PLES FRO "THE TOP 20"

A more detailed analysis was then carried out for each road user problem that had been identified. In each case road safety issues were listed, and recommendations for improvements were noted. Three examples are provided below.

6.1 Problem for people with disabilities: Inadequate provision of dropped crossings

Dropped crossings are provided at private accesses to allow vehicles to enter and leave the carriageway. They are also provided at pedestrian crossing locations to assist all pedestrians to cross the road in safety and comfort.

Pedestrians with mobility problems are likely to benefit most from the provision of dropped crossings. This group includes the elderly, parents with pushchairs, and cyclists pushing their bikes. But it is people in wheelchairs who are most seriously inconvenienced if dropped crossings are not provided, or if they are incorrectly laid.

Safety issues

Some visually impaired pedestrians prefer to have a small upstand of the kerb at a dropped crossing to distinguish between the footway and the carriageway. Whilst this is satisfactory for most other pedestrians, non-flush crossing points can lead to difficulties for people in wheelchairs.

- ◆ An absence of dropped crossings may encourage pedestrians with mobility problems to cross elsewhere – possibly in a more dangerous location.
- ◆ High kerb upstands at pedestrian crossing points could cause people to trip over.
- ◆ Non-flush kerbs could lead to people in wheelchairs crossing elsewhere or becoming "trapped" in the carriageway.

These problems are accentuated by incorrect or inappropriate use of tactile paving.

Possible solutions

- ✓ Ensure that all pedestrian crossing points have flush dropped kerbs suitable for wheelchair access.
- ✓ Ensure the correct use of tactile paving in conjunction with dropped crossings.
- ✓ Discuss specific problem sites with local groups representing disabled road users, particularly where both visually impaired and wheelchair users are involved.

6.2 Problem for cyclists: Inadequate provision of cycle facilities

Cycle facilities are provided to encourage cycling as a mode of transport. Within this, care is taken to ensure that the safety of cyclists is taken into account.

In many cases cycle routes have been provided on footways, by installing either shared or segregated pedestrian/ cycle paths. In some cases cycle lanes are provided within the carriageway.

The main points of conflict for cyclists are at road junctions. At traffic signals, advanced stop lanes have been used to assist cyclists, and at roundabouts cyclists are sometimes encouraged to leave the carriageway and share the footway.

Safety issues

Some new schemes still lack any specific provision, leaving cyclists to mix with motor traffic without any protection. Piece-meal provision of facilities such as toucan crossings and advanced stop lines can leave cyclists stranded between features. Some of the common problems that increase risks for cyclists include

- ◆ Lack of cycle route continuity
- ◆ Missed opportunities such as the provision of a pelican rather than a toucan crossing
- ◆ Poor signing, marking and maintenance of cycle routes
- ◆ Inadequate warning of the presence of cyclists to other road users
- ◆ Poor provision for cyclists at roundabouts

Possible solutions

- ✓ Develop a route based cycle strategy within a locality
- ✓ Undertake cycle user audits to ensure continuity of route, and adequacy of signs and markings
- ✓ Provide traffic calming to reduce the speed of motor traffic
- ✓ Consider site specific remedies at roundabouts such as "continental" road markings

6.3 Problem for vehicle users: Lack of entry path deflection at roundabouts

A roundabout is generally considered to be a relatively safe form of junction control. Right-turn accidents can be eliminated by introducing a roundabout at a cross-roads. However, a roundabout where vehicle entry speeds are high can have a poor accident record.

The advice given to designers is that vehicles should not be able to enter the roundabout on a path greater than 100 metres radius (this is known as the entry path deflection). The tighter the radius, the slower the vehicles will enter the roundabout. Sometimes this 100m radius is not easy to achieve when there are more than two lanes entering the roundabout or where the geometry of the approach roads is unusual.

Safety issues

Lack of entry deflection results in high vehicle approach speeds. This can lead to

- ◆ Vehicles failing to stop at the roundabout give way line resulting in entry and circulating accidents
- ◆ Shunt type accidents when the lead vehicle pulls up sharply
- ◆ Vehicles colliding with street furniture in the central island
- ◆ Unsafe conditions for pedal cyclists and motor cyclists

These problems are accentuated by wet road conditions



The 2nd International Conference on Accident Investigation,
Reconstruction, Interpretation and the Law, October 20-23, 1997

Highway 407 Safety Review: Observations and Impact

Frank Navin

Hamilton Associates, and

University of British Columbia, Civil Engineering

SUMMARY

Highway 407 is a new 69 km, 10 lane electronic toll road north of Toronto and is the largest single infrastructure project ever undertaken in Canada. It is a design build project with a fixed cost of \$928.6 million. The first phase which is the subject of the report is 36 km and has 6 lanes. The Highway 407 Safety Review was initiated because of safety concerns raised by the Ontario Provincial Police and others. The review made 12 recommendations to improve the safety of Highway 407 and future highways. The Ontario government has implemented 11 of the recommendations at a cost of \$15 M. This paper describes the process of arriving at the committee's recommendations, the recommendations and how they have impacted road safety in Canada.

The Highway 407 Safety Review is an important point in the evolution of road safety in Canada. This is the first safety review of a major highway in North America. The results of the review have been widely reported in both the media and the engineering professional press.

INTRODUCTION

The Ontario Provincial Police (OPP), after an unofficial drive along the almost completed first stage of Highway 407, declared it unsafe and a potential killer highway. Their concerns were championed by the Toronto Star newspaper as well as carried by television, and the road's safety became a public issue that eventually required a safety review. Figure 1 is a typical example of the head lines that appeared in many Toronto area newspapers.

Highway 407 is an electronic toll road, one of the first and largest public-private infrastructure projects ever undertaken in Canada. The 69 km, 10 lane, \$928.6 million route crosses the top of Toronto and is developed to satisfy some local commuter traffic as well as commercial traffic that wants to avoid the congestion closer to the city, see Figure 2. The first section that was to be opened in October 1996 links Highway 10 on the west to Highway 404 on the east, with 6 lanes for a total length of 36 km.

As a result of the OPP safety concerns and other interventions, the Ontario Government undertook a safety review. On 15 January 1997 the Ministry of Transportation for Ontario (MTO) commissioned the Professional Engineers of Ontario (PEO) to undertake a Review of Highway 407.

This paper deals with the safety issues the committee studied along the original 36 km section. It provides some suggestions for further investigation and the impact of the review on highway design and safety in Canada.

Police warning engineers of deaths on Highway 407

Independent probe studies new toll road

By BOB MITCHELL
STAFF REPORTER

Provincial police have told engineers conducting a safety probe of Highway 407 that motorists will die needlessly unless centre median barriers are installed.

Armed with statistics, video footage and years of experience, the OPP officers made their case to the independent

design or construct ... so that people would not die on that roadway," OPP Inspector Alex Kehoe said.

"But there are things that can be done to improve on Highway 407," he said.

He said that the highway is a "death trap" and that it is a "disaster waiting to happen."

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Figure 1 Newspaper Headlines

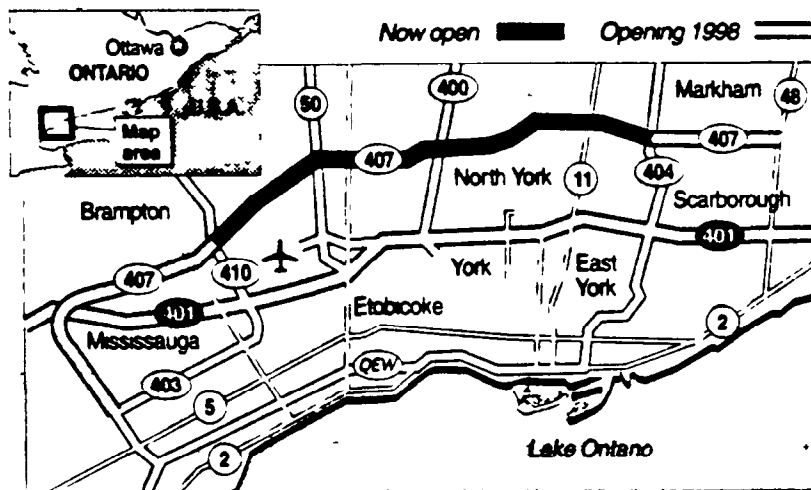


Figure 2 Highway 407

PEO COMMITTEE

In anticipation of being asked to review Highway 407 the PEO contacted about 24 recognized experts on highway design and road safety. Six were asked to join the committee. The committee membership and preliminary terms of reference were approved by the PEO's Board of Directors in early January 1997.

The committee held its first meeting on January 20, 1997 at which time the name of the committee was changed and a few modifications were made to the terms of reference. The name was changed to "Safety Review of Highway 407". The amended terms of reference were:

1. The committee will undertake an independent safety review to address whether appropriate engineering standards were used in the design of Highway 407. This will include a review of the design issues raised by the Provincial Auditor and the Ontario Provincial Police.

- 2 The Committee will also address the appropriateness of the outcome of the value engineering exercise on the design of Highway 407

In carrying out its work, the Committee will

- determine whether the highway meets or exceeds Ontario standards which have a bearing on road safety,
- determine whether the standards used and the design decisions taken in the design of the highway were applied in a manner which appropriately addressed safety,
- determine whether cost-effective opportunities were taken to enhance the highway's safety,
- consider whether there are any seemingly cost-effective opportunities to enhance the safety of the highway which merit consideration by the Ministry of Transportation

THE PROCESS

At the outset the committee recognized that since this was the first safety review of a major new North American highway, it was likely to attract attention not only from engineers, but also from other public-private consortia, the media, and infrastructure financial circles. The committee was placed under tight time constraints because the anticipated highway opening was to be on March 31. The committee had seven official meetings extending over a total of seventeen days, reviewed about 150 documents, met with four stakeholder groups, and delivered the final report on 4 April 1997.

The first task for the committee after refining and accepting the terms of reference was to put together a work plan. We decided to do as much of the work in parallel as possible by assigning tasks to individuals. The tasks included the following:

- 1 OPP issues
 - a median high mast lighting
 - b median width
 - c median bridge piers
 - d tight loop ramps
 - e some ditch configurations, and
 - g median barrier
- 2 Review of plans for conformance with MTO design standards
3. Review of the Value Engineering exercise
- 4 Review of the organizational arrangements and their evolution
- 5 Review of the evolution of the design criteria for Highway 407

The questions asked in each area included,

- 1 the current state of safety related knowledge
- 2 how did the current situation of Highway 407 come about,
- 3 were MTO design standards met
- 4 was safety conscious design undertaken and were cost-effective safety measures considered
- 4 what cost-effective safety measures are available

which had Deputy Ministers from Transportation, Economic Development, Consumer and Corporate Affairs and Finance. All questions of policy were referred to cabinet. CHIC was the successful bidder in April 1994 and the final design-build contract was signed on May 10, 1994 for a fixed price of \$ 928.6 million. During this time the government continued to build Highway 407 in the traditional MTO manner. CHIC had to integrate and work around the MTO projects. The broad organization that finally completed Highway 407 is shown in Figure 3. The major role of each organization in the building of Highway 407 is given in Table 1.

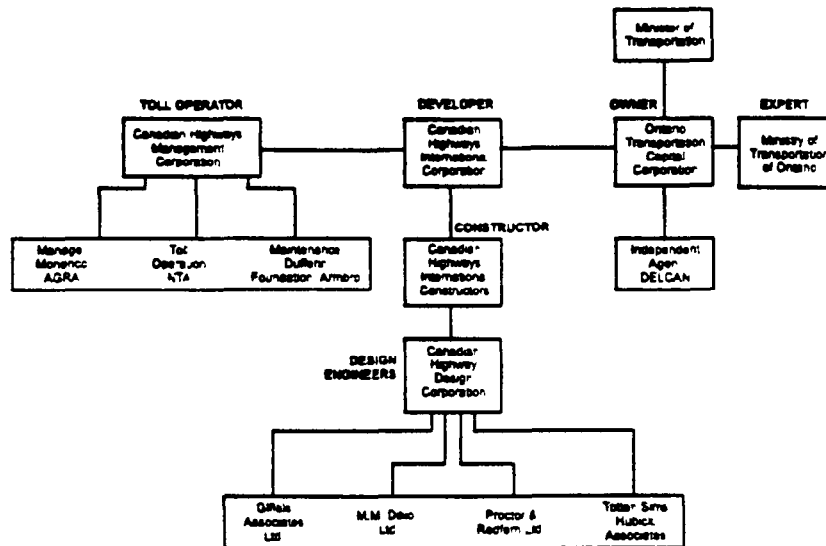


Figure 3 The Highway 407 Development Organization

Table 1 Roles in Building Highway 407

Agency	Role
Owner (OTCC)	<ul style="list-style-type: none"> the owner on behalf of the Government of Ontario
Independent agent (DELCAN)	<ul style="list-style-type: none"> validate progress payments approve that designs met terms of contract quality control and assurance
Expert (MTO)	<ul style="list-style-type: none"> provide expert advice to questions submitted by OTCC
Developer (CHIC)	<ul style="list-style-type: none"> develop Highway 407 operate Highway 407 maintain Highway 407 transfer Highway 407 to OTCC after 35 years
Constructor (CHICConstructors)	<ul style="list-style-type: none"> design Highway 407 construct Highway 407
Design Engineers (CHDC)	<ul style="list-style-type: none"> design Highway 407 construct Highway 407
Specialists	<ul style="list-style-type: none"> provide specialty designs and advice
Operation (CHMC)	<ul style="list-style-type: none"> maintain and operate Highway 407

5. what should be done in the future

Papers were prepared on each topic and they formed the bases of the discussions that led us to our conclusions and the final report.

Because the study was of such a high profile the PEO developed a media plan. There was a press conference after the first meeting of 20 January. Other press briefings were held periodically throughout the project to give factual material to the media. Only the PEO media relations staff and the committee chair spoke to the press. The press recorded some of the committee proceedings for media material. The final press conference was attended by twenty five reporters.

The total effort that went into the review was roughly 4000 person hours some of which were provided as part of PEOs professional responsibility. The total cost was roughly \$500,000 not counting the ongoing PEO costs.

THE DIFFICULTY OF THE PROBLEM

Highway 407 was designed to conform with the Ministry of Transportation of Ontario's Geometric Design Standards and their Roadside Safety Manual. These design standards were comparable to those used throughout North America. This made judging the road's safety difficult, in part because of the relative rarity of collisions, particularly fatalities, and the uniqueness of each highway design. The type of road being investigated is among the safest of roads so what the committee was investigating was a marginal change in safety and the process of increasing safety awareness in design rather than the single issue, "is the road safe?"

HIGHWAY 407 HISTORY

The Highway 407 corridor has a 45 year development history starting when it was designated in 1950. In the late 1970's conceptual studies and some preliminary studies were started. The ministry issued three preliminary design reports, in 1983 and 1987 and by the early 1990s several structures were being built.

The relationship between the public and private interests changed in January 1993 when an innovative tolling partnership idea for Highway 407 was presented to cabinet. The Private sector would assume responsibility for designing, building, operating and maintaining the highway plus collecting revenue. The government would secure financing and retain ownership through a crown corporation. The highway would be returned to government after the 35 year lease period. In February 1993 the Ontario Transportation Capital Corporation (OTCC) was announced as the agency to build Highway 407 and staff assembled. An RFP for a value-engineering exercise, to more efficiently develop Highway 407 as a toll facility was let in June 1993. The value-engineering assessments were used to produce a new set of design criteria. The ministry then issued its request for proposals (RFP) for the design and construction of Highway 407 in September 1993 with a closing date of December 1993.

During the period in November 1993, OTCC was legislated as a crown corporation reporting to the Minister of Transportation, with responsibility to oversee construction of Highway 407. The evaluation of the Highway 407 RFPs was carried out by MTO along with a decision committee.

RESULTS

The committee concluded that "Highway 407 is likely to have similar safety as other 400 series highways in Ontario". The review was divided into a detailed response to the mandate outlined earlier and a section that addressed the broad issues of how to build an appropriate level of safety into roads

Responses to the Mandate

The committee concluded that the development and organizational history did have an impact on the eventual safety of the project. First, CHIC was required to design their portion of the facility within a well-developed design context of structures already in place, and other decisions, many going back to the 1970's, that had already been taken by MTO. Second, the new organizational structure for the Highway 407 partnership changed the design criteria approval process normally used by MTO. The new approval process was not as well defined as the previous MTO process. Finally, our review of the Highway 407 organization failed to establish which, if any agency, had assumed the traditional MTO role as the "guardian of public safety". Our discussion with stakeholders revealed that safety was implicitly considered by all agencies but the loss of a single arbiter of road safety was of concern to the committee

In the opinion of the committee, the value-engineering exercise was given an almost impossible task, that is, propose cost-reduction or other cost-effective methods to develop Highway 407 without reducing the road's safety. In fact, the committee felt that the value-engineering was a government directed cost-cutting exercise. The consortia used what the committee came to understand as an accepted value-engineering practice, which was "if a standard is met, then safety is not changed". Also, some proposed changes, such as the elimination of, or postponing of an interchange are extremely difficult if not impossible to analyze for safety impacts with existing techniques. The committee recommends that value-engineering be continued for highway's such as 407 but that safety be explicitly considered and that the simple adherence to standards is not good enough for safety conscious design

After careful consideration, the committee also agreed with many of the OPP concerns such as, median high mast lighting, median bridge piers, tight loop ramps and the shape of some ditches. The committee did not share their concern about the traction properties of the concrete pavement nor their suggestion for a continuous median barrier.

The committee was concerned by the general acceptance that "if the design standards are met then the safety requirements are met". As an example of this approach, the MTO's clear zone standard of 10 m was rigidly maintained. The fact that a 4:1 side slope actually reduces the level 10 m clear zone to an approximate equivalent of 7 m was not considered by the MTO geometric design standards, the designers, or OTCC

The detailed reviewer of plans for Highway 407 did indicate a number of areas where the MTO design standards may not have been met. There were no as-built drawings so the committee used design drawings and limited field checking (snow covered the highway for much of the review period) to reach its conclusion

Finally, the committee tried to forecast the number of crashes that might occur along the road but could only arrive at rough estimates based on highways with some similar characteristics. Cost-

effective calculations were not carried out except in a few instances such as for the median barrier. The road's safety, relative to other roads, is outlined in Table 2. Some of the actions taken during the road development, such as full illumination, median greater than 22 m and paved shoulders, all tended to improve safety along the entire road. Other design decisions, mostly at point locations, tended to make the road somewhat less safe.

Table 2 Relative Safety* of Selected Elements of Highway 407

Element	Relative Safety				
	Considerably Worse	Somewhat Worse	Somewhat Better	Considerably Better	Impact Extent
Illumination				*	all
Median >22 m				*	all
Paved Shoulders			*		all
High mast lights		*			point
Bridge piers		*			few
Sediment control		*			all
Radius of some ramps		*			few
Median X section		*			all

*rate assigned by F. Navin only, does not appear in committee report

A qualitative estimate of the safety impacts of the improvements suggested by the committee are given in Table 3. Generally, the road will be made somewhat more safe after the implementation of the recommended changes. A significant improvement can be achieved by protecting the high mast lights and median bridge piers to reduce the severity of impacts. The remaining improvements achieve only a modest increase in safety. Since civil engineering infrastructure has been found to be involved in more than half the fatalities on freeways, these changes should reduce fatalities. Also, about a third of all accidents involve the infrastructure, so the number of collisions will only be marginally influenced.

Building Safety into Roads

In the committee's opinion the management of road safety by engineering design and operations requires rethinking. We felt that the present practice of highway design was less than satisfactory since many decisions affecting road safety are not based on the best available factual knowledge. Governments and professional associations need to investigate the impact of design procedures on road safety.

When designing and operating a highway, the road safety failures are not always obvious. The traditional ways of redressing failures found in Structural engineering, for example, do not work well in road safety engineering. To get the right amount of safety into a road, particularly with BOT type procedures, requires a safety "guardian". The committee thought that the best place for such a guardian was within the MTO.

Finally, the committee found an opportunity existed for the police (OPP) and safety engineers (MTO) to cooperatively share information and experiences. They both have valuable experiences and insights. The committee recommended that the Minister of Transportation and the Solicitor

General of Ontario take steps to enhance the sharing of road safety knowledge and experience between the MTO and the OPP.

Table 3 Expected* Amount of Safety Improvement to Highway 407

Device	Somewhat better	Considerably better	Extent	Accepted
Review non-compliant sites	*		point	yes
Crash devices on poles		*	point	yes
Crash devices at piers		*	point	yes
Reshape median	*		all	yes
Rumble strip	*		all	yes
Reshape hydraulic structures	*		point	yes
Barrier extension	*		point	yes
Flatten side slopes	*		point	yes
Toll signs	*		point	yes
Loop ramp guidance	*		few	yes
Loop ramp friction	*		few	no
Repair markings	*		all	yes

*Estimates by F Navin only, does not appear in the committee report

IMPACT OF THE REPORT

The PEO had implemented a media relations plan as already outlined. The report and the procedure to develop the report was well received by the news media. An example of one of the final headlines in a major metropolitan newspaper read "When clear thinking is key, call in engineers" is given in Figure 4. The media relations analysis by the PEO estimated that there were 24 million media impressions between December 1996 and May 1997 generated by the Safety Review. Also, what started out as a potential fight between the police and engineers eventually came to be reported as an objective review by credible professional engineers. After the initial flurry of opinionated reporting of the safety issues, the press reporting became more factual as they were given better information.

The impact on the design of new highways in Canada is already being felt. A call for proposals for a new toll highway has already specified the need to explicitly consider safety and safety audits. Most provincial highway departments are reviewing or starting the steps to implement some form of road safety audit or review.

HOW TO AVOID A HIGH PROFILE PUBLIC REVIEW

The institutional arrangements for BOT projects must be changed to accommodate a guardian of road safety just as there are guardians for the environment and finance. This safety agency or guardian should, ideally have a legislated mandate and be given both the authority and responsibility to deal with issues of traveler safety. The committee recommended that the MTO would be a suitable place for such an agency or guardian.

During the review, the committee became convinced that safety conscious design, that is design which required designers to go beyond simply applying minimum codes or standards, needs to be taught both to the profession and undergraduate students. Safety conscious design includes all the crash reduction devices found in the Forgiving Highway (reduces the consequences of a crash) and the devices that help avoid accidents which are part of the Caring Highway (reduces the probability of a crash). Also the design process should have an adequate "paper" trail that would allow review of the salient features to understand the safety-environment-financial-operational trade-off that need to be made in any design.

Currently there are two techniques that could be used to reduce the chance of delaying a project opening due to public concern, they are Safety Audits and Safety Reviews

Whatever process is used, the emphasis is for ongoing safety analysis before commissioning the road. Experience has found that the 30 percent design point is one of the best points for a formal safety review. This is far enough along in the design process that real circumstances may be considered but not so far along that it is difficult and expensive to change the design. Other reviews should be undertaken at the planning stage, the 50 and 70 percent design points as well as a pre-commissioning audit.



Figure 4 Headlines About the Review

FUTURE WORK

There should be a concerted effort on the part of the engineering profession, academics and major agencies such as MTO, to teach and require safety conscious designs that includes all aspects of the Forgiving Highway and the Caring Highway.

The highway safety research community must develop analytical methods that are easily used by safety professionals for a systematic analysis of new and existing projects. Manuals must be developed for multi-lane roads in more urban areas that outline the best safety design practice. The practice of road safety must be taken from an art to an engineering analytical process. To help form adequately detailed data bases all the institutions of the road safety enterprise such as departments of transportation, police, coroners, insurance agencies, automobile association, and academics must join to share their knowledge and experience.

CONCLUSION

The Safety Review of Highway 407 found a number of deficiencies in the instructional arrangements of BOT that can diminish road safety. Many of the safety concerns of the police are also those of the committee but a few were not

The most constant safety weakness found by the committee in the design process was the prevailing attitude that by meeting some minimum standard, safety was satisfied. The weakness is not unique to highway engineering, and is found in most code based engineering designs, and is, therefore, probably a risk associated with any published minimum standards. Demands for fiscal restraint, requirements of the environment, and other policy matters are legislated, so also should those of road traveler safety

There is a need to encourage safety conscious highway design that includes features of the Forgiving Highway and the Caring Highway. This will require the efforts of the engineering profession, academics and major approving agencies such as MTO to be successfully implemented. Such safety conscious designs should make the repetition of an expensive and exhaustive effort, such as the Highway 407 Safety Review, unnecessary

REFERENCE

Highway 407 Safety Review, Professional Engineers of Ontario, North York, Ontario, Apr 1997
A copy may be obtained from www.peo.on.ca

COMMITTEE:

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Arthur Scott, P-Eng , Retired
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At the time of this review Professor Navin was the President of Hamilton Associates of Vancouver British Columbia, a firm of twenty eight people of whom twenty are engineers with special expertise in road safety engineering. Hamilton also has offices in Ontario as Synectics Transportation Consultants Incorporated and Peru as Peru Consultories International SA